

**Cognitive and Functional Outcome following Traumatic  
Brain Injury or Subarachnoid Haemorrhage**

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Thesis submitted for the degree of  
Doctor of Philosophy  
The University of Edinburgh  
1997



## Declaration

I, Deborah J Hellawell, hereby certify that this thesis:

(a) has been composed by myself

and

(b) that the work contained herein is my own, excepting those areas wherein the work of others is acknowledged.

Date ..... 28 - 10 - 97 .....



## Acknowledgements

The gestation period of a part-time PhD is considerable, and as a result, there are many people whom I must thank. Firstly, I would like to thank all of the patients and their families for their help in participating in this project. I am also grateful to the Scottish Office Home and Health Department, and the Association of British Insurers, for funding this research.

I would also like to thank the late Professor Miller and the Head Injury Research Team at DCN, in the Western General Hospital, Edinburgh; and my colleagues in the Rehabilitation Studies Unit, at the Astley Ainslie Hospital, particularly Kath McPherson.

Special thanks must go to my supervisors: Dr Robert Taylor for his advice and guidance; and Dr Brian Pentland, for teaching me how to write a good sentence, of which this is not one. Thanks also to Kevin, Kenny, Sir John and the lads, for providing a suitable distraction when I probably didn't need one.

I would like to dedicate this thesis to my family, for their constant presence and support. Thank you.

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# Abstract

Long term cognitive impairments are recognised as common consequences of both traumatic brain injury (TBI) and aneurysmal subarachnoid haemorrhage (SAH). Primary injury to the brain resulting from impact and secondary insults arising by various mechanisms contribute to disturbed psychological function in both conditions. The evolution of these cognitive impairments and their association with everyday functional consequences is poorly understood.

The present study was designed to investigate the outcome of 100 surviving patients who were admitted consecutively to a regional neurosurgical unit with a diagnosis of either moderate or severe TBI. An additional group of 44 SAH patients was recruited to enable tentative comparisons to be drawn between groups with acute brain injury arising from these different causes.

At intervals of 6, 12 and 24 months post-injury, global outcome was estimated using the Glasgow Outcome Scale (GOS) and patients were assessed using a battery of neuropsychological tests. Information concerning the extent of the patient's recovery was also collected at each time point.

Poorer GOS outcome was associated with greater severity of initial injury. However, complications arising at the acute stage of treatment also influenced outcome. Because of the limited sensitivity of the GOS, a more detailed outcome scale, the Edinburgh Extended Glasgow Outcome Scale (EEGOS), was devised and applied.

Results of the neuropsychological assessment in the TBI patient groups showed that severe cognitive impairment was typically associated with more severe initial injury. These results are in agreement with those of Rimel et al. (1982) in suggesting that patients with moderate TBI experience a level of morbidity intermediate between those with severe and those with minor TBI, and contrast with those of Anderson et al. (1994) for reasons which are discussed.

Despite the relationship between severity of injury and cognitive impairment, functional problems were reported to a similar extent by relatives of both the severe and moderate TBI patients. The results suggest that the brain injury impacts on everyday life to a greater extent and in many more patients than might be expected on the basis of formal cognitive assessment.

Comparisons between the TBI and SAH groups were heavily influenced by a difference in the estimated severity of initial brain injury, but there were similarities in outcome between groups. A broadly similar pattern of cognitive impairment, although of less severity, was found in the SAH patients, but again functional problems reported by relatives suggested that the injury had more serious effects on everyday life than might be expected from formal assessment.

The results suggest that formal assessment of cognitive function is useful and informative in the conditions studied, but that other measures provide important supplementary information about the ways in which acute brain injury influences the lives of patients.

It has been remarked that an accident which causes injury to the trunk of the body will result in either death or good recovery. However, an accident or condition which causes damage to the brain or nervous system will often result in long term impairment and consequent disability (Jennett, 1996). Such an injury does not lead to a shortened life-expectancy and so the implications for family and carers are significant. For this reason, it is very important to follow up patients who sustain brain injuries to try and assess the degree of residual long term impairment and disability.

London (1967) commented that as medical treatment improved, and the proportion of patients who survived severe head injury increased, so the number of severely disabled patients (or 'lamebrains') rose. Over the past thirty years, the survival rate of patients with traumatic brain injury (TBI) has continued to improve according to some authors (Jones et al. 1994; American Congress of Rehabilitation Medicine, 1995), although others have reported a stable mortality rate (Kraus and McArthur, 1996b). Any improvement in mortality and morbidity is likely to be the result of improved critical care techniques. Likewise, in patients with subarachnoid haemorrhage (SAH), advances in surgical and management techniques have led to improved mortality rates (Ropper and Zervas, 1984; Maurice-Williams and Kitchen, 1994). This present thesis aims to investigate the outcome of patients who survive severe or moderate TBI, or aneurysmal SAH, and the implications of this improved survival rate.

## 1.1 Traumatic Brain Injury

Traumatic brain injury (TBI) has been variously defined. Definitions include

'damage to the brain and/or brain stem due to mechanical injury' (Powell, 1994) or  
'brain injury caused by trauma to the head (including the effects upon the brain of other possible complications of injury notably hypoxaemia and hypotension, and intracerebral haematoma)' (Medical Disability Society, 1988).

A particularly pertinent definition to this present thesis is

'an acquired injury to the brain caused by an external physical force resulting in total or partial disability or impairment' (U.S.Congress Senate, 1992).

Traumatic injury to the brain is caused by a combination of movement of the head, and acceleration and deceleration forces on impact (Long and Webb, 1983). There are a number of ways in which this can occur. The head itself may be stationary when something hits it, as for instance, in the case of assault when the head may be hit with a baseball bat or

hammer. The head itself may be moving when it comes into contact with something stationary, as in the case of a fall. Alternatively, the head may be moving when it hits something which is also moving, as in the example of a road traffic accident (RTA). Traumatic brain injury can also arise if something hits and penetrates the skull and brain, as in the case of a gunshot.

## **TYPES OF TRAUMATIC BRAIN INJURY**

Traumatic brain injury is often categorised as either a closed head injury or a penetrating head injury, with damage being either focal or diffuse. The term 'focal' is used to describe an injury where damage is restricted to a specific area of the brain, and is also used to refer to injuries where there is a space-occupying lesion such as a haematoma. Diffuse injuries refer to widespread damage throughout the brain in the absence of a space-occupying lesion, although contusions may be present (Gennarelli et al. 1982).

### *Closed Head Injury*

A closed head injury (CHI) may be defined as an injury to the head which does not involve penetration of the skull, although a skull fracture may be present in a CHI. A majority of TBIs in Britain fulfil the criteria of closed head injuries. These are caused by the violent movement of the head, leading to immense forces being put on the brain. Patients who have a skull fracture are more likely to have intracranial lesions than those without (Vollmer and Dacey, 1991).

### *Penetrating Head Injury*

A penetrating head injury occurs when an object or missile strikes the skull, breaks it and penetrates the underlying brain. The nature of a penetrating injury means that the damage to the brain is relatively localised or focal, leading to specific impairments of functioning. However, the exact nature of the impairments depends upon which part of the brain has been injured in the accident. Penetrating brain injuries are relatively uncommon in Britain although the incidence of penetrating injuries in the United States is much higher as a result of the greater frequency of shootings.

### *Multiple Injuries*

Severe TBI is often accompanied by multiple injuries. Injury to the chest has been reported in 10%, and injury to the liver or bowel in 11% of TBI patients (Horn and Garland, 1990). Grading systems of multiple injuries have been developed in an attempt to quantify the severity of 'body trauma'. The Injury Severity Score (ISS) (Baker et al. 1974) is one such scale, which involves estimating severity of injury on a scale of 1 (minor) to 5 (critical) for



each of six different body regions. The total ISS is calculated by summing the square of the three most severe injuries to any body region. Baker et al. found that the combination of multiple injuries proved more serious than was expected by adding up their individual effects. She concludes that the ISS provides a simple and reliable method of summarising the severity of multiple injuries in trauma patients.

## **MECHANISMS OF TRAUMATIC BRAIN INJURY**

The types of brain injury depend on a variety of factors including the actual cause of the head injury. If the head is relatively immobile at the time of the accident, such as in an assault, the damage is more likely to be focal and there will be a higher incidence of fractures. If the head is mobile at the time of the accident, such as in an RTA, injury is more likely to be caused by the movement of the brain inside the skull resulting in axonal shearing and diffuse damage throughout the brain (Denny-Brown and Russell, 1941).

### **Primary Injury**

The primary injury to the brain occurs at the time of the accident and can give rise to two types of impact damage: contusions or diffuse axonal injury (DAI).

#### *Contusions*

A contusion is a small bruise resulting from small blood vessels being broken within the brain and bleeding taking place in the surrounding area, leading to brain swelling.

Contusions are usually multiple, and most common in the frontal and temporal areas, irrespective of the site of impact (Teasdale and Mendelow, 1984). This results from the brain coming into contact with sharp parts of the skull as the brain is thrown around.

#### *Diffuse Axonal Injury*

Diffuse damage is caused by the violent movement of the brain and skull at the time of impact. The force of the impact leads to shearing of the axons inside the brain, which are stretched as parts of the brain move relative to one another. In cases of DAI damage occurs to a widespread area of the brain. The computed tomographic (CT) scan of a patient with a diffuse injury can appear normal, and in such cases, the diagnosis of a diffuse injury has often been made on the grounds of persisting disturbances in level of consciousness (Lindsay et al. 1991). However, the development of magnetic resonance (MR) imaging has revealed lesions, thought to reflect diffuse white matter shearing, in patients with no CT abnormalities (Wilberger et al. 1987; Hadley et al. 1988; Smith et al. 1995). As MR imaging becomes more widely available, it is likely to be used increasingly in the diagnosis of diffuse damage resulting from CHI.

## **Secondary Injury**

A TBI is not a single isolated injury which takes place at the time of the accident, but rather a process which takes place over a period of time. Haematomas commonly develop, there may be brain swelling, and secondary physiological insults may occur.

### *Haematomas*

If bleeding inside the brain continues, the amount of blood can build up and form a haematoma or blood clot. If the haematoma occupies a large amount of space, the brain may be squashed to one side causing midline shift and the haematoma may require neurosurgical evacuation. Extradural haematomas (EDH) arise between the skull and the dura, usually in the temporal or temporo-parietal areas as the result of damage to the middle meningeal artery. Subdural haematomas (SDH) form beneath the dura, and sometimes in association with bleeding into the brain tissue, in the context of a 'burst lobe'.

### *Brain Swelling*

Brain swelling, or oedema, is common and arises from an increase in intracellular or extracellular fluid, from a number of causes. There may be a disruption of cell metabolism, leading to an increase in sodium and calcium ions, thereby drawing fluid into the brain cells (cytotoxic oedema). This causes damage to the capillaries, and from there, fluid passes into the extracellular space (vasogenic oedema). Brain swelling can also be caused by an increase in cerebro-spinal fluid (CSF) in cases of obstructive hydrocephalus.

### *Secondary Insults*

Work by Jones et al. (1994) has illustrated that after an injury to the brain, the autoregulatory mechanisms by which the brain controls various physiological functions can be disrupted, leading to the incidence of 'secondary pathophysiological brain insults'. In that study, insults were defined as periods of 5 minutes or more when the values of certain physiological variables fell outwith threshold limits. The exception to this was pyrexia, which was defined as an insult if it exceeded the threshold for one hour or more, to reflect the slower rate of change of temperature compared with other physiological variables. The extent to which the values exceeded the pre-determined thresholds determined the grade of insult, although the threshold values were arbitrarily chosen. Their investigation demonstrated the presence of insults in all severities of TBI, and in all 14 parameters which were monitored. More commonly occurring insults included raised intra-cranial pressure (ICP) and hypoxia. The main difference between groups of patients with severe, moderate or minor TBI was in the grade (i.e. severity) of insult with the most severe injuries



producing the most severe insults. These secondary insults can occur for days after the accident and Jones et al. suggest that they are potentially avoidable with appropriate medical intervention.

#### *Intracranial Pressure*

Raised ICP can be caused by a number of different mechanisms. Haematomas occupying space within the skull, and brain swelling within the enclosed space of the skull, can both lead to an increase in ICP. Other causes include an increase in cerebral blood volume (CBV), and an increase in cerebro-spinal fluid (CSF).

#### *Hypoxic Injury*

Hypoxia refers to a reduced level of oxygen in the tissues. Normally, autoregulatory mechanisms maintain cerebral blood flow to meet the brain's metabolic needs. In TBI, these autoregulatory mechanisms are disrupted and this can lead to ischaemic brain injury, or inadequate blood flow, which in turn causes hypoxia.

### **Surgical Treatment of TBI**

A small number of neurosurgical interventions are commonly used in the treatment of TBI.

#### *Craniotomy*

A craniotomy refers to the surgical removal of a bone-flap in order to evacuate a haematoma, thereby relieving raised ICP and in cases of midline shift, allowing the brain to return to its usual position.

#### *Burrhole*

One or more burrholes can be used in the evacuation of a haematoma, either if deterioration in the patient's level of consciousness is rapid, or in the presence of a chronic SDH.

#### *ICP monitor*

Raised ICP is a common consequence of TBI, especially if the injury is severe. A catheter is often inserted so that the ICP can be constantly monitored. If the ICP becomes higher than a critical value, then the patient is treated with an infusion of Mannitol. Mannitol acts by providing an osmotic gradient, drawing fluid out of the brain tissue and thereby reducing the pressure within the brain itself.

### **COMPLICATIONS**

In addition to the primary and secondary injuries to the brain, the patient may experience other medical complications, either intracranial or extracranial in origin.

## **Intracranial Complications**

### *Post-Traumatic Epilepsy*

Posttraumatic epilepsy (PTE) is a well-known consequence of TBI. It has been reported in over 36% of consecutive admissions to a rehabilitation facility (Armstrong et al. 1990), although a truer estimate of its incidence in the population of CHI patients is likely to be around 5% (D'Allessandro et al. 1988; Fearnside et al. 1993).

### *Hydrocephalus*

Communicating hydrocephalus has been reported to occur in 3.9% of TBI patients (Groswasser et al. 1988). The presence of communicating hydrocephalus may be suggested by a decrease in recovery rate.

### *Traumatic Subarachnoid Haemorrhage*

Some degree of traumatic SAH is commonly seen in TBI. It is an important complication in that it can lead to vasospasm, reducing cerebral blood flow (CBF), causing ischaemia. The presence of traumatic SAH in closed head injury has been reported to be associated with a poorer outcome (Greene et al. 1995).

## **Extracranial Complications**

### *Respiratory Problems*

An injury which causes TBI may also lead to chest injuries. This can cause inadequate ventilation as the result of a pneumothorax or haemothorax. Such complications may increase injury to the brain through hypoxia, thereby influencing outcome (Horn and Garland, 1990).

One of the more frequently observed complications of TBI is aspiration pneumonia. Voluntary components of swallowing are not present in the comatose patient, and the gag reflex may also be affected. This can result in aspiration leading to pneumonia, which in turn causes hypoxic injury to the brain (Groswasser, 1996).

### *Cardiac Problems*

The cardiac system can also be disrupted, again contributing to the amount of secondary damage to the brain. In patients with multiple injuries there may be considerable blood loss. Disruption of autoregulation means that the brain may be unable to compensate for the drop in blood pressure.

## *Nutrition*

It is common for a TBI patient to show a hypermetabolic rate in the acute stage post-injury. This is accompanied by a high nitrogen wastage and glucose intolerance due to partial starvation, with patients reported to lose up to 15% of their body weight per week (Meythaler, 1996).

## **CAUSES OF TRAUMATIC BRAIN INJURY**

The number of potential causes of head injury is high, but in fact most head injuries arise from a very small number of causes. The single most common cause of TBI has been reported to be road traffic accidents (RTAs), including vehicle users and pedestrians (Vazquez-Barquero et al. 1992; Jennett, 1996; Kraus and McArthur, 1996b). The next most common causes are falls and assault. Falls are particularly common in children and the elderly, and in adults, are often associated with alcohol intake. The incidence of assault varies from region to region: it is particularly common in economically depressed areas, and is also related to alcohol and drug intoxication.

Many different types of sport and leisure activities can also lead to TBI, but horse riding and boxing have been reported to have the highest risk (Engberg, 1995). The two sports causing the highest hospital admission rates in Glasgow have been reported to be horse riding and golf (Lindsay et al. 1980).

Some TBIs are sustained at work, more frequently in men than women, and most commonly in people with manual occupations. Causes of such injuries include being hit on the head by a falling object, or falling from ladders or scaffolding.

The cause of injury is also linked to the severity of injury, with RTAs likely to cause severe TBI and pedestrians more likely to sustain multiple injuries than people travelling in vehicles. Falls and assaults are more likely to cause moderate injury. Some sports are likely to cause more severe TBI than others: a riding accident is more likely to cause a moderate or severe injury than is a football accident.

## **SEVERITY OF INJURY**

Over 2000 years ago it was observed that patients were more critically ill after head injury if there was a period of coma than if there was no loss of consciousness (Smith, 1961). The importance of *depth* of coma was emphasised by Symonds (1928), who recognised the distinction between coma and 'clouded consciousness'. Management and treatment of head injuries at this time were much more dependent on observations of the patient, with terms

such as concussion, minor cerebral contusion and major cerebral contusion defined on the basis of observations of the patient over the subsequent hours and days following the injury.

One of the difficulties in comparing studies is that different centres use different definitions to classify severity of brain injury. Indeed, it has been remarked that the different criteria used may account for much of the variability between studies reported in the literature (Medical Disability Society, 1988).

There are two widely accepted ways of measuring the severity of injury. The first of these is the duration of post-traumatic amnesia, originally defined as the duration of impaired consciousness. More recently, the Glasgow Coma Scale (GCS) has been developed to measure the level of consciousness of the patient, and is now used routinely in acute care.

### **Post-traumatic Amnesia**

The term post-traumatic amnesia (PTA) was devised and used to denote the time interval of impaired consciousness (Russell, 1932), and was used as an index of the presence and type of structural cerebral damage (Smith, 1961).

Definitions of PTA have varied. It has been used to denote the period of time from injury to the time when the patient became aware that they had regained consciousness (Russell and Nathan, 1946). A more recent modification took the measure to include a period of time when the patient had regained consciousness and was responding, but was not consolidating memories consistently i.e. the period of anterograde amnesia including the period of coma (Russell and Smith, 1961). In practice, the most widely accepted definition of PTA is the duration of time from injury to the return of continuous day-to-day memory.

#### *Advantages of using Duration of Post-traumatic Amnesia*

There are a number of advantages in using the duration of PTA as an index of the severity of injury. It differs from other indices of severity of injury in that it is assessed during early recovery, rather than at the time of injury (Williams et al. 1984). There are a number of confounding factors which can influence apparent severity at the time of injury, such as alcohol or drug intoxication, which will have a much smaller effect, if any, on the duration of PTA.

In order to standardise the use of PTA as a measure of severity of injury, Jennett and Teasdale (1981) suggested an index of severity based on PTA duration.

**Table 1.1      Index of severity based on duration of post-traumatic amnesia  
(Jennett and Teasdale, 1981)**

Duration of PTA	Classification of Severity
Less than 5 minutes	Very mild
5 to 60 minutes	Mild
1 to 24 hours	Moderate
1 to 7 days	Severe
1 to 4 weeks	Very severe
More than 4 weeks	Extremely severe

The scale is non-linear in accordance with reports of the relationship between duration of PTA and outcome. A difference between PTA of 3 and 6 days has much bigger implications for outcome than a difference between PTA of 43 and 46 days (Haslam et al. 1994).

#### *Difficulties with Duration of Post-traumatic Amnesia*

Despite the advantages in using PTA as an indicator of the severity of injury, there are also some drawbacks. There are difficulties in accurately measuring the duration of PTA. In some patients 'islands' of memory may be noted when the patient is consolidating isolated memories, but this is not consistent. Gronwall and Wrightson (1980) reported islands of memory in more than a third of patients with mild head injury. They found estimates of duration of PTA unreliable, in that 25% of their sample reported different duration of PTA when followed up retrospectively than at the time of their hospital admission. From this, they concluded that PTA should be determined prospectively where possible, because of the unreliable nature of retrospective estimation. However, the classification system used by Gronwall and Wrightson was very detailed, with time intervals of nil; < 5 minutes; 5 - 30 minutes; 31 - 60 minutes; and > 60 minutes. The mean time interval between injury and assessment was 107 minutes, and so despite assessing people on admission to A & E, most estimates were 'retrospective'. Change in estimation of duration of PTA between hospital admission and follow-up is not surprising considering the degree of accuracy required for classification into such short PTA durations.

Attempts to address the difficulties in estimating PTA retrospectively have led to the development of a number of prospective assessment techniques, most notably the Galveston Orientation and Amnesia Test (GOAT) (Levin et al. 1979b). The GOAT was developed as a means of assessing orientation and amnesia during recovery in patients with closed head injury. As well as giving an assessment of the cognitive state of the patient, it provides a

means of estimating the duration of PTA and retrograde amnesia. Performance on the test gives the patient a score out of 100, where a test score of 75 or less is taken to be indicative of continuing PTA. The authors of the test suggest that until the patient's performance improves beyond this point, further cognitive testing should not be carried out.

Nevertheless, the GOAT has been criticised on various grounds. It is essentially a measure of disorientation rather than PTA: it includes two questions concerning retrograde and anterograde memory, but it is possible to achieve a score within the normal range without needing to answer these questions correctly.

Other techniques have been developed to enable prospective measurement (Artiola i Fortuny et al. 1980; Gronwall and Wrightson, 1980) but none of these has been as widely accepted as the GOAT. However, all of these methods are time-consuming and require regular, daily testing of the patients.

Despite the emergence of prospective assessment measures of PTA, other authors have reported that PTA can be measured retrospectively (Engberg, 1995). Estimation of PTA in cases of severe TBI involves relatively long periods of time, and therefore the degree of precision and accuracy is not as crucial as when using it as a measure of minor or mild TBI.

A recent study by McMillan et al. (1996), using a group of severe CHI patients, specifically addressed the issue of whether PTA should be measured prospectively or retrospectively. Prospective assessment was carried out using the GOAT, and the same patients were asked to estimate duration of PTA between 3.5 and six years post-injury by a telephone interview. They found a highly significant correlation between the two estimates ( $r_s = 0.87$ ;  $p < 0.001$ ) suggesting that retrospective assessment is a valid method of determining duration of PTA.

Another difficulty in using duration of PTA as a measure of severity is that different workers have used different time intervals to group patients together. For instance, Brooks et al. (1987a) categorised patients into five groups on the basis of their PTA. The time intervals used were 0 - 7 days; 8 - 14 days; 15 - 28 days; 29 - 60 days; and >60 days. Although the minimum interval of 0 - 7 days is quite broad, this may be reasonable because all patients in the study had sustained severe TBI. Mandleberg (1976) classified patients on duration of PTA in the time intervals of less than one week, 1 - 3 weeks, 4 - 7 weeks and 8 weeks or more, whilst Alexander (1992) used intervals of < 1 hour; < 2 hours; < 1 day; 1 to 7 days; 7 days to 1 month; and > 1 month. Alexander's patients included those with mild TBI and hence there was a need to categorise patients with PTA of short duration into more



specific time intervals. Nevertheless, duration of PTA has been reported as the best indicator of severity of head injury (Newcombe, 1982).

**Glasgow Coma Scale**

The Glasgow Coma Scale (GCS) was devised by Teasdale and Jennett (1974) as a standard method of determining the severity of head injury by assessing level of consciousness. The original existed as a 14 point scale but a modified 15 point version was later developed (Teasdale and Jennett, 1976) and is now the most widely used. It is a simple and reliable way to measure depth of coma, and has been shown to be a robust predictor of outcome. It is based on an assessment of the patient's capacity to function on three sub-scales:

- best eye opening response
- best verbal response
- best motor response

The total score is the sum of scores on the three subscales. Details are given in Table 1.2 below.

**Table 1.2      The Glasgow Coma Scale (Teasdale and Jennett, 1976)**

Eye Opening	Verbal Response	Motor Response
1 = nil	1 = nil	1 = nil
2 = pain	2 = sounds	2 = extension
3 = to sound	3 = words	3 = abnormal flexion
4 = spontaneous	4 = confused	4 = normal flexion
	5 = oriented	5 = localising to pain
		6 = obey commands

Someone who is fully conscious will have a GCS of 15, and the lowest possible score is GCS 3.

*Advantages of using the Glasgow Coma Scale*

One of the biggest advantages of using the GCS is that it has been very widely adopted for measurement of level of consciousness in TBI patients (Langfitt, 1978), thus enabling comparisons between studies and patient populations. From a clinical point of view, it enables estimation of severity at the time of injury and allows early management decisions to be made on the basis of the patient's level of consciousness (Vollmer and Dacey, 1991).

### *Difficulties with the Glasgow Coma Scale*

Two slightly different versions of the scale exist: the 14 point scale has a 5 point motor scale, and the 15 point version has a 6 point motor scale. This can lead to confusion when comparing studies from different centres (McMillan and Greenwood, 1993; Kraus and McArthur, 1996a).

Another problem with using the GCS is that discrepancies arise according to the timing of the assessment. Glasgow Coma Scores are routinely recorded at regular and frequent intervals, from the time of arrival of paramedics at the scene of an accident, often until the patient is discharged from hospital. Some studies use GCS on admission to hospital in categorising severity of injury, whereas others use the patients' lowest GCS within 24 hours of admission (Hall and Johnston, 1994). Teasdale and Jennett (1976) recommended the use of GCS at six hours post-injury, but this is not always feasible. Many patients with more severe injuries will be paralysed, intubated and ventilated by six hours post-injury making assessment of GCS impossible. In cases of more minor TBI, patients may not seek medical advice for several hours after their injury.

A related difficulty arises in cases where the patient needs to be paralysed and ventilated for transfer from the scene of the accident, or from a referring hospital, to the neurosurgical unit. The influence of the paralysing and sedative medications means that it is not possible to measure GCS. In cases of severe head injury, the patient may be paralysed and ventilated in the Intensive Therapy Unit (ITU) for many days after the injury. In these cases, it is usual to assess the level of consciousness immediately prior to paralysing and sedating the patient, and the grade of injury is based on this GCS.

The GCS is often used as a basis for collapsing severity of injury into three categories: severe (GCS 3 - 8), moderate (GCS 9 - 12) or mild or minor brain injury (GCS 13 - 15) (Capruso and Levin, 1992; Macciocchi et al. 1993; Jennett, 1996). This division into three categories was originally made arbitrarily (Rimel et al. 1981; Rimel et al. 1982) and a recommendation for their consistent use has been endorsed by others (Clifton et al. 1992). However, the issue is again confused by the use of alternative definitions by other authors (Conzen et al. 1992; Fedoroff et al. 1992).

There has been some speculation about the usefulness of GCS in defining mild TBI. Jennett (1996) noted that of those patients with mild TBI, a minority will develop some form of complication. Other reports would appear to substantiate this. Dacey et al. (1986) studied a group of 610 hospitalised patients with minor TBI (i.e. GCS 13 - 15). Eighteen (3%)



required neurosurgical intervention for their injuries, with the most frequently observed lesion being a subdural haematoma. A similar proportion of minor TBI patients required neurosurgical treatment in the studies of Harad and Kerstein (1992), and Stein and Ross (1992b).

Williams et al. (1990) found that patients with mild head injury but with complications such as intracranial lesions, or a depressed skull fracture, more closely resembled those with moderate head injury than patients with minor head head injury and no complications. The measures used included neuropsychological testing between 1 and 3 months post-injury, and the Glasgow Outcome Scale (GOS) (Jennett and Bond, 1975) at six months post-injury. Stein and Ross (1992a) found the same incidence of intracranial lesions requiring surgery in 106 patients with GCS scores of 13 as in a group of 341 moderate TBI patients (GCS 9 - 12), which led to their recommendation that moderate TBI be extended to include those patients who were GCS 9 - 13.

Gómez et al. (1996) carried out a retrospective analysis of 2484 patients with mild TBI defined as GCS 13 - 15. Neurosurgical intervention was required in 0.6% of those who were GCS 15, 4.5% of those who were GCS 14, and 26.7% of those who were GCS 13. The higher incidence of loss of consciousness, skull fracture, neurosurgical treatment, and neurological deterioration in patients who were GCS 13 - 14 led to the recommendation of the use of an additional category to differentiate them from patients who were GCS 15 (Gómez et al. 1996).

Yet another difficulty in using the GCS is that a reduced level of consciousness may be due to drug or alcohol intoxication (Vollmer and Dacey, 1991). Alcohol is known to be a contributory factor in many cases of TBI. Acute alcohol intoxication was clearly indicated in 51% of patients tested in a study by Vazquez-Barquero et al. (1992). Kraus and Nourjah (1988) reported alcohol testing in a third of minor TBI patients, with two thirds of those tested proving to be at or above the legal limit of alcohol intoxication.

Thus GCS is an important measure of severity of injury in the acute stage, but it is not without some drawbacks.

### **Duration of Coma**

Duration of coma is sometimes used to estimate severity of injury in patients with severe TBI (Levin et al. 1976; Katz and Alexander, 1994). As the GCS is routinely assessed at

regular intervals as part of neurological observations on the ward, it should be possible to measure duration of coma from nursing records.

However, there are a number of problems associated with the measurement of duration of coma. Although it correlates positively with PTA as one might expect, it has been suggested that its duration is even more difficult to define (Newcombe, 1982).

Katz and Alexander (1994) observed that duration of coma 'was almost never reported explicitly in the acute hospital records' and used the criterion of obeying commands to denote its end. The potential inaccuracy in this approximate estimation allowed only broad time intervals to be used in their analyses.

Another potential cause of inaccuracy in assessment of duration of coma results from the use of paralysing and sedative agents as part of patients' routine acute care, so that duration of coma is artificially affected by medication. The decision as to when to 'wake up' the patient by lightening the dosage will be an important influence on the duration of coma.

In patients who drift in and out of coma, a problem lies in the definition of the end of coma, and how reliably it is reported.

### **Post-coma Disturbance**

A recent paper has reported the potential usefulness of 'post-coma disturbance' as a prognostic indicator of outcome (Ellenberg et al. 1996). Post-coma disturbance (PCD) is defined as the number of days beginning at the end of coma to the time the patient regains continuous memory. The authors' use of the term PTA to describe PCD is misleading, and there are a number of inconsistencies in the report which cast the results and conclusions into doubt. In addition to this, measurement of PCD must be open to the same criticisms as measurement of duration of coma, and duration of PTA. Error may creep in at both the estimation of end of coma and at the estimation of regaining of continuous memory, making the usefulness of PCD as a measure of severity questionable.

### **INCIDENCE OF TRAUMATIC BRAIN INJURY**

It is difficult to estimate the true incidence of TBI. Many people who sustain mild or minor TBI may fail to seek medical advice and so be excluded from estimates of incidence.

Patients with multiple injuries may be misclassified and instances of TBI overlooked. A recently published report of the incidence of TBI in the United States in 1992 suggested

'the true hospital discharge occurrence of TBI, therefore, is somewhere in the range of 194,000 to 377,100 persons' annually (Kraus and McArthur, 1996a).

The difficulty in estimating incidence is reflected in the breadth of range of this estimate.

In epidemiological studies, the use of number of patients admitted to hospital is of limited value because of the variability of admission policies (Jennett, 1996). A problem arises when comparing annual figures from one neurosurgical unit because changes to the structure of the National Health Service (NHS) have affected policy in the management of head injury. This is illustrated by Miller et al. (1992) who reported three annual rates covering a nine year period in a regional neurosurgical unit (RNU). A change in management guidelines during the study period led to a decrease in the number of patients admitted with minor TBI. The number of patients admitted with severe TBI remained constant, but there was a decrease in the number of patients admitted with moderate TBI, either directly or via referring hospitals, believed to reflect a real decrease in the number of patients sustaining a moderate injury rather than a change in admission policy. This is upheld by the fact that the number of patients admitted directly and those admitted via referring hospitals decreased by an approximately equivalent degree.

In the United Kingdom, the annual incidence of severe TBI per 100,000 of the population has been reported as 'approximately 8' cases, with 'approximately 18' cases of moderate TBI (Medical Disability Society, 1988), and 250 - 300 cases of minor TBI, with severity defined according to duration of PTA rather than level of consciousness. Other authors have calculated an estimated incidence of severe head injury as 14 - 16 per 100,000 (McMillan and Greenwood, 1993) using GCS as the basis of their definitions. Others have suggested that the ratio of mild : moderate : severe TBI is of the order of 8:1:1 on the basis of hospital admissions (Kraus and McArthur, 1996b).

The incidence of TBI varies from country to country, and region to region. For example, Nell and Brown (1991) estimate the incidence of TBI to be 316 per 100,000 of the population in South Africa, whilst in Spain, the incidence has been estimated at 91 per 100,000 of the population (Vazquez-Barquero et al. 1992).

Although causes of TBI are similar throughout the world, the incidence of TBI from different causes varies. For example, the incidence of TBI resulting from violent assault is much more common in the United States than in European countries (Engberg, 1995).

As well as differences arising between countries, there are some difficulties in making a direct comparison between national figures and regional figures because of the variability in populations. For example, large parts of Scotland are very rural, and the causes of head

injury in such regions are likely to differ from those in an inner city area. It might be expected that the number of assaults will be fewer, but that more accidents will happen at work because of the greater proportion of people employed in manual work. Also, RTAs are more likely to happen at greater speed, causing more severe injuries than RTAs in the city, where traffic is travelling much more slowly. Thus both regional and national variation also contribute to the difficulty in giving precise figures of the incidence of TBI.

Specific studies of annual rates of the incidence of TBI have shown a trend for a decrease in incidence, and a resulting decrease in the number of deaths (Richardson, 1990; Miller et al. 1992). This may be accounted for, at least in part, by greater safety regulations at work, and the increasing number of effective safety features built into cars. The introduction of laws to reduce drinking and driving, and to make the wearing of seat belts compulsory, has helped in the case of RTAs (Miller and Jones, 1985), and the introduction of airbags is expected to contribute to further reduction.

### **CHARACTERISTICS OF THE HEAD INJURED POPULATION**

The causes of head injury are such that the population of head injured patients is not a representative cross-section of the population as a whole. Typically, the incidence of TBI is much higher in men than women. The ratio of males to females varies according to cause of injury, and from study to study, but is usually of the order of 2:1 or 3:1 (Vogenthaler et al. 1989; Kraus et al. 1994). There is also a gender difference in the severity, with severe TBIs more frequently sustained by men than women (Kraus and McArthur, 1996b).

Traumatic brain injury is most common in young adults, with the 15 - 24 year old age group commonly reported to have the highest incidence of TBI (Kraus and McArthur, 1996b). Road traffic accidents, which are estimated to comprise 40% of accidents resulting in head injury, often involve young adults, especially men (Medical Disability Society, 1988). Likewise, assaults are most common in young men and are often related to alcohol and drug usage. There is another peak in incidence in the elderly, with the over 60 age group reportedly at greater risk reflecting an increase in falls in the elderly. Falls are more common in the elderly, in bad weather or when they are under the influence of alcohol. This is perhaps more of a problem in Edinburgh because of the architecture and housing in the city. Many people live in Victorian tenement buildings with stone stairs, and so falls may be more common and be likely to have more serious consequences.

Some studies report a higher incidence of TBI in lower socioeconomic groups. This may be accounted for by several factors: a higher rate of manual labour in lower socioeconomic



groups; poorer housing; older vehicles with fewer safety features; and an increasing likelihood of violent assault (Rimel et al. 1982; Kraus and McArthur, 1996b).

## 1.2 Subarachnoid Haemorrhage

Subarachnoid haemorrhage has been likened to TBI in that it involves a combination of both diffuse and localised injury to the brain, and the results of both may be similar (Eames, 1988). As with TBI, advances in medical techniques over recent years have led to an improvement in mortality after SAH (Ropper and Zervas, 1984; Moriyama et al. 1995). Surgical repair of aneurysms has become routine over the last thirty years, but studies prior to the mid 1960s can be used to demonstrate the natural course of SAH with conservative management. Six month survival rates of 69%, 72% and 58% in patients following ruptured aneurysms of the posterior communicating, middle cerebral and anterior communicating arteries respectively, were reported by Storey (1967). However, as more patients survive the initial incident, more people, with potentially many years of life ahead of them, are left with residual impairments and disability (Storey, 1967; Sonesson et al. 1987).

Subarachnoid haemorrhage occurs as a result of bleeding from ruptured intracranial vessels whereby the blood enters the subarachnoid space. A number of risk factors have been shown to be related to the incidence of subarachnoid bleeding. These include hypertension, smoking, alcohol abuse and poor nutrition (Clinchot et al. 1994). There are several causes of SAH and these shall be considered in turn.

### **CAUSES OF SUBARACHNOID HAEMORRHAGE**

The most commonly reported sources of spontaneous SAH are aneurysms and arterio-venous malformations.

Aneurysms account for a majority of all cases of SAH, with estimates of the proportion of SAH caused by aneurysms in the region of 70 - 75% (Lindsay et al. 1991) or 60 - 75% (Bannister, 1992). Aneurysmal SAH is caused by the rupture of an intracranial aneurysm, with the resultant blood leaking into the subarachnoid space. Aneurysms arise from a weakness or defect in the blood vessel wall, which then dilates abnormally. They most commonly occur at vessel bifurcations, are usually saccular in shape, and vary in size from a few millimetres to several centimetres in diameter, with bigger aneurysms less prone to rupture. The defects can arise as a result of trauma, degenerative vessel disease or infection, but many are congenital weaknesses (Bannister, 1992). The formation of aneurysms is believed to be linked to a number of factors including hypertension, smoking, oral

contraceptive use, female gender, and ageing. However, little is understood about the factors which cause the aneurysm to rupture (Pickard et al. 1992).

Arterio-venous malformations (AVM) are abnormalities of the arterial and venous systems, and are thought to account for approximately 5% of SAH. They can be classified in terms of their size, as this is of particular importance in that smaller AVMs are more likely to bleed than larger ones, but they are less likely to rebleed. Arterio-venous malformations can change in size as a result of blood pressure and flow.

Other causes of spontaneous SAH include hypertension, tumours or anticoagulants, although the incidence of these causes is not clearly specified.

### **PRESENTING FEATURES OF SUBARACHNOID HAEMORRHAGE**

Commonly reported symptoms of SAH include sudden onset severe headache, neck stiffness, photophobia or disturbed vision, vomiting, and decreased level of consciousness. Headaches are usually in the occipital region, or behind the eyes.

In some patients, focal signs develop, such as a limb weakness, dysphasia or cranial nerve abnormalities. These usually result from a blood clot causing compression of the cranial nerves, the formation of an intracerebral haematoma, or ischaemia attributable to vasospasm. In other patients, the aneurysm may produce some focal abnormalities prior to rupture. Pyrexia and hypertension are also possible indicators of SAH. The severity of the symptoms at onset is related to the severity of the haemorrhage.

Intracranial haemorrhage is the most common presentation of AVMs, occurring in around 50% of patients. Other symptoms, which can occur with or without intracranial bleeding, include seizures, paraesthesias, hemiparesis, dizziness and diplopia.

### **MECHANISMS OF SUBARACHNOID HAEMORRHAGE**

Rupture of an aneurysm leads immediately to raised ICP, and the lowering of cerebral perfusion, contributing to loss of consciousness where present. Intracranial pressure soon returns to normal in cases where the aneurysm bleeds into the subarachnoid space, whilst in cases where rupture leads to the formation of an intracerebral haematoma or acute hydrocephalus, ICP remains high and in some cases life threatening.

### **Surgical Treatment**

There are a number of surgical techniques available in the treatment of aneurysmal SAH. The optimal and most common method used to prevent rebleeding from a ruptured

aneurysm is to clip the aneurysm neck (Lindsay et al. 1991). Other techniques, such as endovascular coiling, are gaining popularity although clipping is still more commonly used.

## **COMPLICATIONS**

The initial SAH is often the beginning of a series of related problems which can occur in the days, months or years following onset. As with TBI, complications can be either intracranial or extracranial in origin.

### **Intracranial Complications**

Many studies have demonstrated the influence of medical complications on outcome following SAH. Immediate post-acute complications include rebleeding, vasospasm and delayed cerebral ischaemia whilst longer term complications such as hydrocephalus and epilepsy are not uncommon (King and Martin, 1994). In addition to this, investigation of patients with aneurysmal SAH show that approximately 30% are found to have multiple aneurysms (Lindsay et al. 1991).

#### *Rebleeding*

The most serious complication following aneurysmal SAH is rebleeding, although the increase in clipping of aneurysms has led to a decrease in the incidence of rebleeding. In patients who are not surgically treated, the incidence of rebleeding within the first 28 days is 30%, of whom 70% die as a result (Lindsay et al. 1991). The risk of rebleeding greatly reduces over the first six months following the initial SAH, but never falls below 3.5% per year. The effects of a rebleed are usually more severe than the first bleed and the risk of death is over twice that of the initial incident.

#### *Vasospasm*

A frequent complication of aneurysmal SAH is vasospasm, or constriction of one or more arteries, occurring in approximately 60% of patients. Vasospasm is believed to be an important factor in the development of delayed cerebral ischaemia. Of those patients who develop vasospasm, 20 - 30% suffer delayed cerebral ischaemia (DCI) as a result (Dowling and Dacey, 1996), most frequently in the 4th to 12th days post-haemorrhage, although it can develop within 24 hours or several weeks later. Of these, 30% die and 50% of survivors show permanent neurological deficits. The cause of vasospasm is uncertain but it is believed to be unlikely to be a result of one factor in particular.

### *Hydrocephalus*

Hydrocephalus is another common complication of aneurysmal SAH. The incidence of acute hydrocephalus necessitating surgical treatment has been estimated at 15 - 20%, with the use of a ventricular drain or shunt the most common intervention (Dowling and Dacey, 1996).

### *Epilepsy*

The incidence of epilepsy following aneurysmal SAH has been estimated at between 9 and 26% (Clinchot et al. 1994) with the first seizure occurring in most patients within four weeks of the aneurysm rupture. Others have reported the incidence to be approximately 15%, and linked to rebleeding, middle cerebral artery (MCA) aneurysm rupture, infarction and shunt-dependent hydrocephalus (Dowling and Dacey, 1996).

## **Extracranial Complications**

### *Cardiac Problems*

Cardiac complications are occasionally reported after SAH, taking the form of either myocardial infarction or cardiac arrhythmias. These are believed to arise as a result of catecholamine release caused by ischaemic damage to the hypothalamus.

### *Pulmonary Oedema*

This is another complication reported occasionally following SAH, and is likely to be the result of sympathetic discharge, typified by 'pink, frothy sputum' (Lindsay et al. 1991).

## **SEVERITY OF INJURY**

One of the difficulties inherent in reviewing and comparing studies of SAH is that until recently, there have been a number of scales used to grade the severity of SAH.

### **WFNS Scale**

Drake et al. (1988) reporting on a meeting of the World Federation of Neurological Surgeons (WFNS), suggested that as many as 37 systems had been used for grading SAH, of which four were in common use. These four were the scales of Botterell et al. (1956), Hunt and Hess (1968), Nishioka (1966) and the International Cooperative Study on the Timing of Aneurysm Surgery (Sahs et al. 1981). The WFNS Committee worked for a number of years on the development of a new scale for SAH based on the scientific information available, in order to establish a 'simple, reliable, clinically valid neurological grading scale'. Using data from 3521 patients enrolled in the International Cooperative Aneurysm Study, analysis suggested that the two factors which were most important in terms of outcome were level of



consciousness and the presence of a focal deficit such as aphasia or hemiparesis. The WFNS Committee used this information to devise a scale comprising five grades, based on an estimate of consciousness using the Glasgow Coma Scale, and the presence or absence of a focal deficit. The boundaries between grades were selected to share common characteristics of the four commonly used earlier scales. Details of the grading system are given below.

**Table 1.3      World Federation of Neurological Surgeons Subarachnoid Haemorrhage Scale**

WFNS Grade	Glasgow Coma Scale	Motor Deficit
I	15	Absent
II	14 - 13	Absent
III	14 - 13	Present
IV	12 - 7	Present or absent
V	6 - 3	Present or absent

Studies reported since the introduction of the WFNS Grading Scale have enabled comparisons between various groups using different surgical or management techniques, thereby allowing an evaluation of different methods to be made. This is of particular importance in a situation where techniques in management and surgery are developing rapidly.

### **Glasgow Coma Scale**

A recent paper by Gotoh et al. (1996) has questioned whether the boundaries used in the WFNS scale are the most suitable, and whether or not the GCS alone is more useful. Gotoh et al. studied a consecutive series of 765 patients who were surgically treated for aneurysms within one week of SAH, and followed them up at six months using the Glasgow Outcome Scale (Jennett and Bond, 1975). They found that although the borderlines between the grades of the WFNS scale occur at points corresponding to GCS scores of 15 to 14; 13 to 12; and 7 to 6, the differences in six month outcome seemed to fall between groups with initial GCS scores of 15 to 14; 12 to 11; 7 to 6; and 4 to 3. Gotoh et al. suggest that some of these differences may be clinically meaningful, and that it may be useful to modify the boundaries between grades on the WFNS scale to take account of these findings. However, they also point out that the distribution of GCS scores on admission showed relatively few patients at the severe end of the scale, i.e. semi-comatose or comatose, and they recommended that a future study should investigate this in more detail. They conclude that

the level of consciousness measured using the GCS provides a useful indicator of severity of SAH, and can be used as a prognostic tool in predicting outcome.

### **INCIDENCE OF SUBARACHNOID HAEMORRHAGE**

There have been a number of reports in the literature of the incidence of SAH. These vary from 4 to 55 per 100,000 of the population (Pakarinen, 1967) but a more precise figure of 10 - 16 per 100,000 of the population has been cited by a number of authors since then (Lindsay et al. 1991; Clinchot et al. 1994). One of the reasons for variation in estimates of incidence is a reflection of the true variation in the incidence. Figures quoted for the population of Iceland differ from those cited for the United States (Gudmundsson, 1973), whilst a large study by Rinne et al. (1996) confirms that the incidence of middle cerebral artery (MCA) aneurysms is higher in the population of Finland than has been reported in studies from other countries.

Ruptured aneurysms have been estimated to occur in between 6 - 12 per 100,000 of the population. Locksley (1966) reports that the site of ruptured aneurysm is, in descending order of frequency, the internal carotid artery, anterior communicating, middle cerebral, basilar, anterior cerebral, and cerebellar arteries respectively. More recently estimates have suggested that the most common sites, in descending order of frequency, are the anterior communicating artery (35 - 40%), internal carotid artery (30%), middle cerebral artery (20 - 25%) and posterior circulation (10%) (Lindsay et al. 1991).

Arterio-venous malformations account for a much smaller percentage of cases of SAH than ruptured aneurysms. The estimated incidence of AVMs suggests that they are present in 140 per 100,000 of the population, although not all AVMs rupture. A proportion of people with AVMs will remain asymptomatic for life (Bannister, 1992).

### **CHARACTERISTICS OF THE SUBARACHNOID HAEMORRHAGE POPULATION**

The SAH population is a much more representative sample of the general population than is the TBI population. Aneurysms are often caused by developmental abnormalities and do not arise as a result of lifestyle, although there is some evidence to suggest that the likelihood of their rupture may be affected by external factors such as smoking.

Subarachnoid haemorrhage occurs most frequently in people between the ages of 40 and 60, but can be found in any age group, including children. However, the age at which it is likely to become symptomatic is related to the cause of SAH. Aneurysms are most likely to rupture between the ages of 40 and 55, and are more common in women than men

(Bannister, 1992). Studies of AVMs suggest that bleeding occurs at a younger age, most commonly between the ages of 20 and 40 years (Lindsay et al. 1991). It is less likely to be fatal than aneurysmal SAH and development of further complications such as vasospasm and DCI are less frequent.

In people under the age of 40, SAH is more common in males, but in people over the age of 40 it is more common in females (Bannister, 1992). This is linked to the cause of SAH, with AVMs being more common in males than females, and aneurysm rupture being more common in females than males.

In addition to this, age has been linked to severity of the SAH. In a study of 778 patients Lanzino (1996) found that 66% of patients under the age of 40 were Grade I on admission, compared with only 33% of those aged 70 years or over.

### 1.3 Comparison of TBI and SAH

#### *Similarities*

From this review of the existing literature it can be seen that similarities arise in the acute course of both TBI and SAH. Both causes result in injury to the brain, and the initial injuries are often followed by periods of secondary injury and further intra- and extracranial complication. These include intracranial complications such as hypoxia, hydrocephalus or post-traumatic epilepsy, in addition to extracranial complications such as cardiac and respiratory problems.

Both TBI and SAH are sudden, unexpected, and can be life-threatening. Both can cause lasting neurological, neuropsychological and physical difficulties, which can affect the reaction of survivors.

#### *Differences*

Perhaps the most obvious differences between patients with TBI or SAH lie in the demographic details of the two patient groups. The TBI population is much younger and male dominated than the SAH population, and of different socio-economic distribution.

Another difference between the two groups is that TBI is often the result of an accident which causes multiple injuries to other body systems, whereas SAH affects the central nervous system alone. In addition to this, SAH can be the beginning of a long and complicated medical course in cases of multiple aneurysms, or rebleeding late after the

initial insult. Traumatic brain injury is more likely to be a unique event, although the incidence of TBI is much higher in those who have already sustained one such injury.

Chapter 2 focuses on patients' recovery and outcome in more detail, comparing the extent and nature of disability, with particular emphasis on cognitive functioning, following TBI or SAH.

## Chapter Two Recovery and Outcome

The ability to predict the extent to which an individual will be affected by an injury to their brain is desirable in terms of appropriate levels of provision and supervision, and production of realistic aims for the patient's future. However, the great individual variation in speed and extent of recovery makes prediction of final outcome very difficult.

### Recovery

London (1967) noted that the extent of recovery following severe head injury was often limited. He wrote that:

"Discharge from hospital is all too often the prelude to the longest and most frustrating period of all; a period in which the prospect of truly rehabilitating the patient sometimes gives way to the hope that he will be able to do something to earn a living and finally to resigned acceptance that a once productive and creative member of the community has become a heavy and lifelong burden upon his family." (p.475-6)

One of the difficulties surrounding the discussion of recovery is that it is often assumed to mean a complete recovery. In other words, it is taken to be recovery of the individual to their former level of functioning. In cases of sickness a patient is likely to make a full recovery but brain injury often results in long term impairments and subsequent disability and in such cases, recovery is taken to be improvement to the individual's best achievable level of functioning. It is often said that the patient has made a good recovery 'considering how bad he was' despite having significant disability (Jennett, 1984). There is great variation between individuals in what this optimal level will be, and it is impossible to say at which point recovery is complete.

### Outcome

The term outcome is used in discussions of brain injury to describe level of functioning resulting as a consequence of the injury. It does not imply a full recovery, although it can be used in cases where the patient is completely recovered, as well as in those cases where recovery is incomplete.

For the purposes of this thesis, and in the knowledge that acute brain injury is rarely followed by a full and complete recovery, the term 'outcome' will be used to describe the consequent level of functioning of the patients. The term 'recovery' will be used to denote the extent of recovery.



When reviewing the literature concerning outcome following any form of brain injury, two relevant areas become apparent. The first involves detailed investigation of aspects of the acute stage of injury and their influence on global outcome. The second area focuses on detailed investigation of outcome, such as cognitive functioning, and the relationship with more general aspects of the acute stage of injury. Thus it is necessary to review studies of global outcome, and more detailed studies of cognitive sequelae.

## **GLOBAL OUTCOME**

There is much variability between individuals in the nature and extent of impairment following injury to the brain. Some people may have predominantly physical difficulties, whilst others may make a complete physical recovery but remain cognitively or emotionally affected. In order to draw overall comparisons between groups of patients with wide ranging problems, gross measures of outcome have been used.

One way of estimating outcome has been to study the rates of return to work (Van Zomeren and van den Burg, 1985; Ip et al. 1995; Ponsford et al. 1995b). Reports of rates of return to work vary, but there are difficulties when drawing direct comparisons between studies. One problem arises in that there are many ways in which return to work can be classified and categorised. As a result, a number of scales have been developed to provide a standardised method of categorising level of work.

Van Zomeren and van den Burg (1985) looked at return to work in 55 patients, two years after severe head injury. They reported return to work on a scale of five levels, ranging from working at their former level (58% of patients), to not working (16% of patients). However, the authors do not report the percentage of people who were not working prior to their injury making interpretation of the data difficult. In addition to this, they do not give clear criteria for their definition of 'severe head injury'.

Other difficulties are caused by studies being carried out in different countries, at different time intervals post-injury, and by investigating outcome in patients with injuries of different severity (Crepeau and Scherzer, 1993).

Although return to work may provide a useful guide in population studies, there are many other contributing factors which influence return to work on an individual level. Much may depend on the patient's employer, and their willingness to accommodate an employee who may not be able to work at full capacity, especially in the first months after injury. Small firms may not be able to manage with the temporary loss of a worker through head injury



for an indeterminate period of time, and this may lead to redundancy. Larger firms may be able to accommodate the needs of an employee by keeping their post open for them to return when they are able. Also, larger firms are more likely to be able to offer alternative employment if there are reasons why the patient is unable to return to their former job.

In the current economic climate, the rate of unemployment is high and it is difficult for many people to find work. There is an increasing trend for people to work on fixed short-term contracts, and long-term work is much more difficult to find than in previous years. Others have suggested that age is a crucial determinant of return to work, with employers reluctant to keep on older employees with TBI, who have a reduced working life ahead of them (Humphrey and Oddy, 1980). These factors are likely to influence the rates of return to work, and such problems have led some workers to conclude that return to work is not a sensitive measure of outcome (Oddy and Humphrey, 1980).

Another measure was used by Pazzaglia et al. (1975), who devised a four-point outcome scale based on social reintegration. Severe TBI patients were followed up at least two years post-injury to determine the quality of their reintegration. Forty-nine percent of patients died, 10.7% were not reintegrated, 6.3% were partially reintegrated, and 34% were fully reintegrated.

Other standard scales have been devised by which to assess global outcome, the most commonly used of which is the Glasgow Outcome Scale (GOS).

### **The Glasgow Outcome Scale**

The GOS was devised by Jennett and Bond (1975) as a practical scale to enable evaluation of patients' outcome following TBI. Because of the complexity of outcome following damage to the brain, it needed to have a limited number of well-defined outcome categories so that it could be used reliably by different observers. The original five point scale fulfilled these criteria, with the five outcome categories<sup>1</sup> being:

- 1        Dead
- 2        Persistent Vegetative State
- 3        Severe Disability
- 4        Moderate Disability
- 5        Good Recovery

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<sup>1</sup> Some authors report the GOS grades in the opposite order. The present thesis uses the original grading system of Jennett and Bond throughout: 1 = Dead through to 5 = Good Recovery.

The use of the GOS as a worldwide scale to evaluate outcome in head injured patients was recommended to enable comparisons between different studies (Langfitt, 1978). It is now the most commonly used outcome measure in recovery following head injury (Wade, 1992) and has been used as a measure of outcome following acute brain injury of different aetiologies (Jennett, 1984).

The main benefits of the GOS are its simplicity and resulting reliability which make it suitable for use in large multicentre trials of head injury (Clifton et al. 1992).

The main criticisms are that the small number of categories leads to insensitivity, and so the scale is unable to reflect small or subtle changes during the recovery process. The limited number of outcome categories means that two patients graded within the same category may differ enormously. Also, ratings of different abilities are collapsed into one score, and so change along different dimensions cannot be differentiated from one another, leading to masking of some aspects of recovery.

Another related criticism is in the use of subjective terms, such as 'good' or 'moderate', which may obscure quite considerable degrees of disability (Medical Disability Society, 1988). Hütter and Gilsbach (1993) argue that the GOS is biased toward physical and neurological deficits, and that patients classified as having made a 'good recovery' may have other long-term deficits. There are other reports in the literature which would suggest that the category definitions may be open to misinterpretation. For example, Laiacina et al. (1989) and Vermeulen et al. (1992) both define the category 'severe disability' as 'patient conscious but totally dependent on others to get through daily activities'. However, the original authors' definition of severe disability includes patients who are totally dependent through to those who are able to maintain their self-care in terms of activities of daily living within their room or house and only require help over and above this (Jennett and Bond, 1975). The issue is further clouded by the provision of slightly different definitions, on at least two subsequent occasions, by the original authors (Jennett et al. 1981; Brooks et al. 1986b). Nevertheless, the GOS continues to be the outcome measure most widely used in acute brain injury research.

There are other practical issues which arise when considering how to use the GOS. Originally, the reliability was tested by face-to-face interview with the patient, leading to perfect agreement in more than 95% of cases (Jennett et al. 1981). The most thorough study of reliability was carried out by Maas et al. (1983), which led them to recommend that the GOS should be based on an interview with the patient and relatives, as outcome based on

information from letters or telephone contact may be highly unreliable. Despite this, the GOS continues to be used without reporting details of how it has been completed (Clifton et al. 1992) or with a combination of several different completion methods used within one study (Ellenberg et al. 1996).

In both TBI and SAH a number of factors have been identified which are known to influence the extent of recovery, and thus the patients' outcome. These factors include:

- Severity of injury or bleed
- Incidence of secondary insults or damage
- Site and type of lesion
- Complications
- Age of the person at the time of the injury
- Time since injury
- Rehabilitation

The remainder of the chapter will cover each of these factors in turn, firstly in discussion of outcome following TBI and secondly in discussion of outcome following SAH.

## 2.1 Traumatic Brain Injury

### **Global Outcome**

Jennett (1984) reported that six months following severe TBI less than a fifth of the survivors remained severely disabled. Gray et al. (1994) reported similar findings at one year post-injury, with 22% of severe TBI patients classed as severely disabled, 26% as having moderate disability, and 50% a good recovery. In the same report, 71% of patients with moderate TBI experienced moderate disability, and 29% a good recovery, although the sample size of the moderate group was only seven.

Levin et al. (1990) looked at outcome in 300 patients, one year after sustaining a severe TBI. Of the 259 patients available on whom outcome could be assessed, 8% were vegetative, 23% severely disabled, 21% moderately disabled and 49% were classified as having made a good recovery.

All of these studies reveal a fairly consistent pattern, with roughly half of the severe TBI patients classified as 'good recovery' and the other half remaining disabled to some extent.

## **Cognitive Outcome**

Symonds (1928) reported that the mental consequences of head injury were

‘inability to concentrate, defective memory, indecision, loss of emotional control and rapid fatigability of the mental processes’.

He continued by emphasizing that impaired memory and intellectual function were ‘valuable signs of organic cerebral damage’ and that these impairments would probably be found more often if formal testing of cognitive function was employed. He also noted the similarity in symptoms ‘commonly observed in the course of recovery from moderate or severe brain injury’ (Newcombe, 1982).

Over the subsequent 70 years, there has been an increase in the quantity of research aimed at investigating cognitive sequelae of head injury, and with it, an increase in the number of assessment instruments designed to measure the level of various aspects of cognitive functioning.

Cognitive deficits after TBI are common. The most frequently reported cognitive sequelae are problems with memory, concentration, and speed, but also include language and perceptual deficits. The effects of cognitive impairment are often overlooked in the presence of more obvious physical impairment and handicap. However, cognitive impairments can have the most disabling consequences, and are often the greatest causes of distress for the family and relatives (Brooks, 1991; Evans, 1994). In most cases of minor TBI these are relatively short-lived and resolve within a few days or weeks (Levin et al. 1987b) but in more severe TBI they can be persistent.

Cognitive impairments following brain injury have been reported to be significantly related to global outcome (Levin et al. 1979a). Ryan et al. (1992) report a study suggesting that reading comprehension, memory and depression were the most significant predictors of vocational outcome, whilst others report total number of neuropsychological symptoms to be the strongest predictor of return to work (Godfrey et al. 1993).

Factors shown to influence global outcome, and studies of their relation to more detailed cognitive outcome, will now be discussed in turn.

## **Severity of Injury**

One of the most important factors known to affect recovery and outcome is the severity of the initial injury itself. In general, the more severe the injury the poorer the patient's chances of making a complete recovery and the more likely they are to experience long term

disability as a result of the injury. However, in some instances, patients with relatively minor TBI are left with substantial morbidity and long term impairment (Rimel et al. 1981) whilst some of those with severe TBI are left relatively unimpaired (Long and Webb, 1983).

Katz and Alexander (1994) looked at different measures of severity of injury, and their usefulness as predictors of outcome. They found that measures of severity, particularly PTA, were correlated with outcome at both 6 and 12 months post-injury in patients with diffuse axonal injury, but correlated poorly in patients with focal brain injury.

Numerous studies have pointed to a significant correlation between duration of PTA and outcome (Karzmark, 1992) and it is widely accepted as a useful prognostic indicator (Long and Webb, 1983). The longer the duration of PTA, the less likely the patient is to return to work, and the longer it takes to do so if this occurs at all (Oddy et al. 1978). Aronow (1987) suggests a strong linear trend in the relationship of severity as measured by PTA duration and outcome, whilst other studies show a non-linear trend of PTA duration and outcome (Haslam et al. 1994).

Brooks et al. (1987a) found significant differences in many areas of function between patients with PTA durations of above or below two weeks, whilst others have reported that for patients with a PTA of one week or more 'full recovery will be the exception rather than the rule' (Engberg, 1995).

Although the duration of PTA has been shown to be related to outcome, it should be noted that it is of most value in predicting outcome in patients with diffuse brain injury. Typically, patients with focal brain injury have relatively short periods of PTA compared to those with diffuse damage, even when the severity of injury as measured using the GCS is similar. It is believed that the duration of PTA is directly related to the degree of structural damage in patients with diffuse injury (Smith, 1961).

Langfitt (1978) recommended the use of the GCS and GOS as reliable and valid measures which were developed to complement one another. However, studies have reported mixed results, with some describing early GCS scores as being of limited predictive value in terms of outcome (Uzzell et al. 1987b), and others reporting it as being strongly related to outcome (Bishara et al. 1992) and related to memory impairment (Dikmen et al. 1987).

Brooks et al. (1980) compared various measures of severity of injury in relation to cognitive outcome. The measures of severity were selected to assess both diffuse and focal damage.



Coma duration and duration of PTA were used to assess severity of diffuse damage. The presence of haematoma (and operative treatment if necessary) and presence of skull fracture (and laterality and type of fracture) were used to assess focal damage. Cognitive performance was measured on a range of tests designed to assess intelligence, learning and memory, language abilities and perceptual and constructional skills. Brooks et al. concluded that the only measure which showed a significant correlation with impairment of cognitive performance was duration of PTA. Duration of coma was not a significant predictor of later outcome, although patients who were in coma for 24 hours or less did have higher scores on cognitive assessment than those who were in coma for more than 24 hours, suggesting a lesser degree of impairment.

Mandleberg (1976) reported an investigation of test performance on the Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1945) and found that duration of PTA was related to reduced performance IQ up to six months post injury, and reduced verbal IQ up to three months post injury.

Duration of coma has been shown to be only weakly related to cognitive outcome (Brooks et al. 1980; Alexandre et al. 1983), and whilst Ellenberg et al. (1996) report that the duration of post-coma disturbance (PCD) was predictive of outcome at discharge and six months post-injury, there are inherent difficulties in measurement of the duration of PCD. Other reports suggest that the Injury Severity Score (ISS) is related to outcome in TBI patients (Engberg, 1995).

### **Secondary Insults**

The incidence of secondary insults to the brain has been shown to affect outcome, with duration of hypotension, pyrexia and hypoxia significantly related to mortality (Jones et al. 1994). Raised ICP has been related to impaired memory post-injury (Uzzell et al. 1986); in another study, raised ICP was found to be related to memory disturbance at six months post-injury but by 12 months this relationship had disappeared (Levin et al. 1991).

The development of monitoring equipment to reveal the extent of secondary insults is relatively recent and the extent of the effects of secondary insults on long term outcome remains to be seen. It is thought that many insults are avoidable and as treatments improve, so the incidence of insults will be reduced.



## **Site and Type of Lesion**

The site and type of damage to the brain have been shown to influence patients' outcome. A patient who has an injury causing diffuse damage to the brain is likely to experience impairments of memory, concentration and reasoning. Some patients may perform within normal limits on tests of cognitive function, but have much slower response times. Patients sustaining focal injury may experience difficulty with specific functions, with the type of functions affected dependent on the area of the brain which is damaged (Lezak, 1995). For example, damage to the left hemisphere of the brain is likely to give rise to language difficulties. A particularly consistent observation is that damage to the frontal lobes of the brain is likely to give rise to change in behaviour and personality (Walsh, 1994).

Brain contusions are often located in the frontal lobes, and the consistency of reports of associated changes has led to the use of the term 'frontal lobe syndrome'. This term is used to denote characteristics such as loss of inhibition, lack of initiative and spontaneity, impulsive behaviour and lack of anxiety or concern for the future. Cognitive changes associated with frontal lobe damage include loss of abstract thinking and reasoning, lack of mental flexibility, and impaired planning and problem solving.

The site of lesion identified using CT scanning has been shown to be related to differential performances on subtests of the WAIS (Uzzell et al. 1979). In the same study the type of lesion was found to influence cognitive outcome with a higher mortality rate for patients with DAI than either focal or diffuse swelling. Surviving patients with DAI made greater improvement.

## **Complications**

Both intra- and extracranial complications can influence long term outcome. Pazzaglia et al. (1975) reported a mortality rate of 49% in patients who were in coma as a result of a TBI. Of the 49% who died, three quarters died as a direct result of their brain lesions, whilst the remaining quarter died as a result of 'extracranial causes' or complications. Deaths from complications and extracranial causes tended to occur from the beginning of the second week post-injury.

More recently, Stein and Spettell (1995) developed a two dimensional scale on which to classify CHI, called the Head Injury Severity Scale (HISS). One dimension was based on severity as estimated using the GCS, but by adding a 'complications' dimension they were able to improve prediction of outcome as assessed using the GOS at six months post-injury.

Specific complications have been shown to correlate with outcome. Post-traumatic epilepsy has been related to poorer neuropsychological test performance (Dikmen and Reitan, 1978), and also to poorer outcome in terms of survival (Corkin et al. 1984; Walker and Blumer, 1989). Groswasser et al. (1988) found that patients with communicating hydrocephalus achieved a poorer vocational outcome than those patients without it.

### **Age**

Another factor frequently cited as influencing outcome is age of the patient at the time of the injury. Although no two head injuries are ever the same, it is often reported that children recover more quickly and more fully than adults who have injuries of similar severity. However, recent work has suggested that this is not the case, and there is growing support for the idea that injury to a young, developing brain can have a more devastating effect than equivalent injury to an adult brain (Webb et al. 1996).

Pazzaglia et al. (1975) reported the outcome of 280 patients with acute post-traumatic coma. Their results suggested that below 20 years of age was the 'positive limit' for a full recovery, i.e. a higher than average proportion of these patients recovered. Forty years was the positive limit for survival, and at age over 60 years, the probability of death was much greater than survival. Vollmer et al. (1991) also found that older patients with severe TBI showed a higher mortality rate and greater morbidity than the younger patients in their study, as did Teasdale et al. (1979).

### **Time Since Injury**

Time since injury has been reported to be important in terms of long-term outcome (Stratton and Gregory, 1994). Most studies have concentrated on outcome in the first year post-injury, but a few studies have investigated the longer-term future. Brooks et al. (1987b) investigated the rates of return to work in a group of severe TBI patients 2 to 7 years post-injury. They reported an employment rate of 29% post-injury compared with 86% pre-injury.

In another study, Brooks et al. (1986a) looked at outcome 1 year and 5 years post-injury in a group of severe TBI patients. They found an increase in the number of difficulties reported by relatives between 1 and 5 years in all areas of function, although behavioural and personality change contributed most to the amount of stress experienced by relatives or carers.

Thomsen (1984) reported a follow-up 10 to 15 years post-injury in a group of very severe TBI patients, who had also been seen at 2.5 years post-injury. She found that many patients were experiencing long term deficits, but that there was evidence of continued improvement since the 2.5 year assessment, with more patients returned to some form of employment, although this was mainly sheltered work.

Thus the evidence suggests that improvement can continue for many years post-injury. One of the difficulties in interpreting studies of recovery over time is that the use of averaged scores can mask individual variation in the patterns of recovery. Change over time is not synonymous with recovery, and improved functioning in some patients may be cancelled out by deterioration in functioning of other patients when looking at mean scores.

### **Rehabilitation**

Another factor which has been shown to influence outcome is the availability of rehabilitation. Aronow (1987) reported that despite greater severity of injury, a group of rehabilitation patients returned to a similar level of functioning as a less severely injured non-rehabilitation group. The timing of the rehabilitation intervention is also important and has been shown to be more effective if it is implemented early after injury if possible (Cope and Hall, 1982; Timmons et al. 1987).

### **POSTCONCUSSION SYNDROME**

Meyer (1904) described

‘easy fatigue, slowness of thought, inability to keep impressions, irritability.....  
headaches and dizziness’

as among the symptoms experienced by patients following concussion (Szymanski and Linn, 1992), whilst Symonds (1928) described the three most common symptoms of TBI to be headache, giddiness, and mental disability.

Since then, more detailed descriptions of these symptoms have been provided and other sequelae added. Commonly reported symptoms include headache, dizziness, fatigue, irritability, sensitivity to noise and/or light, impaired memory and/or concentration, and anxiety (Long and Webb, 1983; Powell and Wilson, 1994; Ohry et al. 1996). Collectively, these sequelae are known as the postconcussion syndrome (PCS). The symptoms are typically associated with mild or minor head injury, and concussion, whereby any loss of consciousness is short-lived and the patient regains full consciousness within minutes - hence the term ‘postconcussion syndrome’. Patients who have sustained a minor or moderate TBI frequently report symptoms such as headache, dizziness, fatigue, and memory

and concentration problems in the early stages post injury. In some patients these symptoms will persist (Vollmer and Dacey, 1991). However, these symptoms have also been reported following more severe TBIs (Brooks et al. 1987a; Alexander, 1992; Dikmen et al. 1993). Tiredness is a common complaint following TBI, but poor memory is the most frequent, and is reported by both patient and relative (Levin, 1992).

The existence of a PCS has recently been acknowledged by the American Psychiatric Association (1994) in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), who propose a set of criteria to indicate the presence of, what they term, 'postconcussional disorder'. The fundamental criterion cited is:

'an acquired impairment in cognitive functioning, accompanied by specific neurobehavioural symptoms, that occurs as a consequence of closed head injury of sufficient severity to produce a significant cerebral concussion' (p706).

The type of cognitive impairment likely to be seen is either a difficulty in attention or memory, and the neurobehavioural symptoms include:

- tiredness
- sleep disorder
- headaches
- dizziness or vertigo
- irritability or aggression
- anxiety, depression or mood swings
- personality change
- apathy or lack of spontaneity

The DSM-IV criteria state that at least three symptoms should be present as a result of head trauma, and persist for at least three months. The postconcussional disorder will detrimentally affect the person's social and occupational activities, signifying a reduced level of functioning.

Szymanski and Linn (1992) carried out a review of the PCS, focusing on complaints by people who had suffered concussion or mild TBI. Commonly reported symptoms of PCS reported were irritability, fatigue, headache, memory and concentration problems, and dizziness.

The study of Dikmen et al. (1993) investigated the presence of post-concussion symptoms in patients with severe TBI, and found that some of these symptoms persisted for up to two



years post injury. They used the Head Injury Symptom Checklist (HISC) to identify changes in the presence of 12 symptoms following moderate or severe head injury. Thirty-one patients were assessed at 1 month, 1 year and 2 years post injury. They found that the presence of symptoms was high, and that although physical symptoms such as headache and tiredness improved over time, cognitive difficulties remained constant, or were reported increasingly often over time.

The symptoms typical of PCS are often seen following more severe head injuries. If PCS is caused by physiological changes resulting from injury to the brain, as has been suggested, then it would seem a likely consequence of TBI, or acute brain injury per se, in a broader context.

## 2.2 Subarachnoid Haemorrhage

### **Global Outcome**

As was described in Chapter 1, the incidence of SAH remains relatively constant, but with advances in medical techniques the number of patients who survive is increasing. As the surgical techniques have advanced, the mortality and morbidity in the treatment and management of SAH have improved, leading to an increasing interest in the outcome of surviving patients. The number of studies has burgeoned over the last 15 - 20 years but there are many difficulties in comparing the results directly.

Most studies of outcome following SAH have looked specifically at patients with aneurysmal SAH. This is the most frequent cause of SAH and has been estimated to account for 60 - 75% of cases of SAH. Some studies have restricted their criteria even further to investigating outcome in patients following aneurysm rupture at a specific site (Barbarotto et al. 1989; Laiacona et al. 1989). Others have investigated outcome in surgically treated patients only (Sonesson et al. 1987; Stenhouse et al. 1991). Many investigators have looked at outcome in 'good grade' patients only i.e. patients who are WFNS grades I and II (Ropper and Zervas, 1984; Maurice-Williams et al. 1991) or grades I, II and III (Ljunggren et al. 1985; Tidswell et al. 1995) at the time of presentation.

For many years, the outcome of patients following SAH has been documented, but it is only relatively recently that standard measures have been adopted, thus enabling comparison between studies and patient populations. Many reports of SAH estimate global outcome in terms of 'good', 'fair' or 'poor' (Vermeulen et al. 1992) but following the recommendation of Drake et al. (1988) the GOS has become widely accepted as a standard measure of

outcome in this patient population. However, there is a relative dearth of literature on the outcome of these patients in terms of detailed assessments of cognitive functioning. This was noted by Clinchot et al. (1994) who commented that the

‘focus on physically based outcome measures fails to consider the often severe cognitive and behavioural deficits that can occur after SAH’ (p1346).

However, the issue of outcome is clouded by the presence of the many medical complications in this patient group, such as rebleeding or further aneurysm rupture. In these cases, it is probable that the second brain insult will cause more damage than the initial one, thereby confounding the effects of the original bleed.

Artiola i Fortuny and Prieto-Valiente (1981) carried out a retrospective study of 192 patients who were surgically treated for intracranial aneurysms over a five and a half year period. A number of different outcome measures were used, such as physical independence, return to work, and subjective well-being. The results showed that 70% returned to full-time work with 51% totally unaffected in terms of job situation, whilst only 40% reported ‘feeling as well as before their illness’. The use of a number of measures revealed the importance of choice of measure of outcome in influencing the results. This strengthens the argument for a standard, universally accepted measure of outcome. The use of the GOS with SAH patients has improved the situation, and enabled comparisons to be made between studies.

Table 2.1 below shows the outcome of surgically treated patients in three different studies.

**Table 2.1            Comparison of outcome in surgically treated patients with aneurysmal subarachnoid haemorrhage**

Study	Sample size (n)	Time of Outcome	GOS1	GOS2	GOS3	GOS4	GOS5
Gotoh et al. (1996)	765	6 month	12%	5%	9%	12%	62%
Maurice-Williams + Kitchen (1994)	267	12 month	9%	0%	3%	5%	84%
Rinne et al. (1996)	457 MCAA	12 month	13%	0%	10%	15%	62%

The study of Gotoh et al. (1996) followed 765 consecutive patients surgically treated following the rupture of an aneurysm. This provides some interesting baseline data on global outcome in a large patient sample. However, in the study by Rinne et al. (1996), outcome is only given for patients following middle cerebral artery aneurysm (MCAA). The paper by Maurice-Williams and Kitchen (1994) reports outcome for 400 patients



treated either surgically or conservatively, and data must be extracted if looking at surgically treated patients only.

The above studies show similar levels of disability following SAH, although it should be remembered that these are patients who have had surgical treatment of their ruptured aneurysm, and are more likely to have been 'good grade' patients. Looking at all 400 patients in Maurice-Williams and Kitchen's series, i.e. in those who were surgically or conservatively managed, the level of good recovery is only 61%, and rate of death is 31%. The remaining 8% of patients survived with varying degrees of disability.

A number of studies report surprisingly good outcome (Barbarotto et al. 1989; Laiacona et al. 1989) but a note of caution should be exercised when interpreting these findings. These particular authors describe the GOS category 'severe disability' as patients who are totally dependent, and so it may be that misinterpretation of the GOS is contributing to an over-optimistic report of outcome.

McKenna et al. (1989a; 1989b) provide two reports of the same patient group. Their main conclusion is that

'patients recovering from an uncomplicated history of SAH should expect no permanent disruption to their cognitive or emotional life' (p366).

They stress the importance of a positive approach to prognosis if the patient has no neurological deficits, emphasising that the patient and relatives need reassurance but nothing more. Their conclusion is somewhat surprising in that they dismiss 13 patients (16% of their sample) who have neurological deficits, as 'best thought of as exceptions to the general rule' and do not consider them further.

### **Cognitive Outcome**

Patients who survive their SAH and have no neurological deficit are often reported to have made a good neurological recovery. However, it has been shown that many of these patients can experience long term neuropsychological impairments (Ljunggren et al. 1985; Vilkki et al. 1990), which are frequently missed by purely neurological assessment. Takaku et al. (1979) reported that psychological symptoms were the most common type of 'complication', and were reported in 11.5% of their sample of 939 surviving patients. Thus it has been argued that any evaluation of outcome should include a neuropsychological assessment (Hütter and Gilsbach, 1993).

The consistency of studies reporting cognitive impairment in conjunction with good neurological recovery in SAH patients has led to a flurry of studies which have investigated neuropsychological outcome in more detail.

### **Severity of Subarachnoid Haemorrhage**

One of the most important prognostic factors in SAH is the patient's initial level of consciousness. A number of studies have shown that the lower the level of consciousness on admission the higher the likelihood of a poor recovery (Takaku et al. 1979; Gotoh et al. 1996; Rinne et al. 1996).

Gotoh et al. (1996) followed up 765 patients with surgically treated aneurysms, and compared the patients' Glasgow Coma Score on admission with their Glasgow Outcome Scale score at six months. The overall correlation between GCS pre-operatively and GOS at six months was highly significant ( $r_s = 0.615$ ,  $p < 0.001$ ).

There is an important implication of the grade of severity on outcome. Neurosurgical centres vary in their admission policies, which has the resultant effect of varying the proportion of poor grade patients reaching different neurosurgical units. This has an immediate and obvious influence on the overall results of management and surgery between units (Maurice-Williams and Kitchen, 1994), which can be misleading. Therefore, when looking at outcome studies it is important to look at the grade of patients in the sample. If two studies which investigate outcome in consecutive series of patients are based in units with different admission policies, any difference in outcome may simply be a reflection of these different admission systems.

### **Site of the Lesion**

It might be expected that the effects of aneurysm rupture will vary according to the site of the aneurysm. There is some evidence to suggest that this is the case, although a number of studies of neuropsychological function have demonstrated patterns of cognitive impairment which are typical of widespread diffuse damage.

Rupture of an aneurysm at the junction of the anterior communicating (ACoA) and anterior cerebral (ACA) arteries can lead to an intracerebral haemorrhage affecting the frontal lobes. The observation of memory impairment and personality change following ACoA aneurysm rupture led to the notion of an 'anterior communicating artery syndrome' (ACoA syndrome) (Alexander and Freedman, 1984; Irle et al. 1992).

Alexander and Freedman (1984) investigated amnesia in a group of 11 patients following surgical treatment of ruptured ACoA aneurysms. The results showed a memory impairment, characterised by anterograde amnesia and failure to form new memories concurrent with a pattern of lethargy and agitation in patients post-operatively, followed by periods of confabulation and denial of illness.

Irle et al. (1992) report impaired long term memory following ruptured ACoA, with short term memory and recognition memory being less affected. Emotional and behavioural changes in their sample included elevation or depression of mood and energy levels, impaired judgment, poor emotional control, and loss of spontaneity.

The ACoA syndrome has been particularly associated with memory disorders, and several reports have described it as Korsakoff's syndrome (Takaku et al. 1979) or 'Korsakoff-like' (Logue et al. 1968). Typically, patients are described as confused, confabulating and showing a lack of insight. In some cases there is a period of retrograde amnesia and the patient may be oriented to an earlier period in time. In contrast to their memory impairment, they may show no signs of intellectual or language dysfunction (Parkin and Leng, 1993).

The patients described show problems typical of frontal lobe dysfunction, as may be expected in view of the proximity of the ACoA to the frontal lobe, and the likelihood of a ruptured ACoA aneurysm causing frontal lobe lesions. However, not all studies of cognitive outcome following ACoA aneurysm show these results.

Tidswell et al. (1995) reported a study of the cognitive outcome of a series of patients admitted consecutively for surgical treatment of an aneurysm. All patients were WFNS Grade I to III. For analysis, they were divided into two groups: one consisted of 20 patients treated for ACoA aneurysms, and the other consisted of a group of 17 patients treated for 'non-anterior' aneurysms. The findings showed no differences on cognitive assessment between the ACoA group and the 'non-anterior' group.

Likewise, Richardson (1989) found no difference in the severity of memory impairment between ACoA aneurysm patients and those with aneurysms at other sites.

## **Complications**

Complications have been shown to influence outcome in SAH patients. Van Gijn et al. (1985) reported an association between acute hydrocephalus and poorer outcome following aneurysmal SAH.

Vasospasm has been shown to be the most important cause of post-operative disability (Artiola i Fortuny and Prieto-Valiente, 1981), and has also been reported to be the best predictor of long term cognitive impairment following surgically treated ruptured ACoA aneurysms (Stenhouse et al. 1991).

Juvela (1992) reported a study of 291 SAH patients, assessed at 12 months using the GOS. Heavy drinking during the year before SAH was a significant prognostic factor for poor outcome. Although the incidence of rebleeding and DCI was similar in drinkers to non-drinkers, the effects were more severe in heavy drinkers, leading to an increase in the incidence of severe disability and mortality. This would suggest an interactive effect between the complications and patients' habits.

## **Age**

Age is an important factor in SAH. There has been a long-established finding that the older the patient, the higher the mortality and morbidity, and the less likely their chance of making a good or complete recovery. This has affected surgical practice, in that there has been a 'traditional limit' of 65 years for patients undergoing aneurysm surgery. Again, improvements in modern surgical techniques and anaesthetics have changed this, leading to older patients receiving operative treatment for ruptured aneurysms, with the proviso that their clinical condition is stable (Bannister, 1992).

Age is also important in relation to outcome, and several studies have shown a worse outcome in older patients (Hutter and Gilsbach, 1993). In some cases, patients have been divided into 'young' or 'old' age groups, whereas other studies have correlated age and outcome as a continuum (Ljunggren et al. 1985).

Older patients have been reported to have poorer outcomes than young patients following SAH, having a worse grade SAH on admission, and a higher incidence of severe complications (Lanzino et al. 1996). Outcome at 3 months using the GOS was worse with increasing age.

Artiola i Fortuny and Prieto-Valiente (1981) reported a decrease in patients' outcome until the age of 60 years, and then an increase i.e. patients between the ages of 50 and 60 had the poorest outcome. The authors suggest that the patients over the age of 60 are more sturdy than the patients in their 50s, and so if they survive they will have a better outcome. It may be the case that only the sturdier individuals in their 60s survived but unfortunately no data are given concerning the death rates of patients in the two age categories and so it is not possible to compare death rates of patients in their 50s with those in their 60s.

### **Time Since Haemorrhage**

Ljunggren et al. (1985) suggest that

'the passage of 3½ years is insufficient for completion of the recovery process' (p678).

This raises many questions concerning the large number of retrospective studies which have reported outcome following SAH. In many retrospective studies, the timing of assessment of outcome varies over a very wide range. Artiola i Fortuny and Prieto-Valiente (1981) report outcome in a group of patients ranging between 18 months to 5½ years post-haemorrhage; whilst De Santis et al. (1989) investigated neuropsychological outcome in 114 patients at a mean interval of 45.8 months post-operation, but ranging from 7 to 115 months. Similarly, Laiacona et al. (1989) report neuropsychological functioning in 43 patients at a mean interval of 46.8 months post-operation, ranging from 16 to 67 months. If recovery over time continues for several years, as proposed by Ljunggren et al., then the variation in time of assessment reported in these other studies will hamper interpretation of the data.

### **Rehabilitation**

Few studies have reported investigations of rehabilitation and SAH. Soryal et al. (1992) noted similarities in the neurological and psychological profiles of TBI and SAH patients treated in their unit, whilst Clinchot et al. (1994) emphasised the importance of establishing the cognitive, behavioural and social sequelae of SAH because of

'their significant impact on post-hemorrhage recovery, rehabilitation, and reintegration' (p1348).

## **2.3 Comparison of TBI and SAH**

In Chapter 1, some of the underlying mechanisms of TBI and SAH were described, and brief comparison between the two types of acute brain injury revealed some similarities in the type of damage and complications which such injuries may involve. Therefore, it seems likely that there will be some overlap in the types of impairment and disability experienced by the two patient groups.



Early reports of outcome following either TBI or SAH were difficult to compare because of the lack of standard assessment measures available. This situation has improved greatly with the widespread use of the GCS and GOS, but there are still problems with many of the existing studies reported in the literature.

A brief comparison of outcome following TBI and SAH reveals a number of similarities between the two patient groups. Studies of global outcome have revealed considerable levels of disability in some patients who survive either TBI or SAH. More detailed investigations have shown that cognitive deficits are relatively common following both types of acute brain injury. In particular, similarities have been drawn between patients with frontal lobe syndrome resulting from TBI, and ACoA syndrome resulting from SAH. However, the literature reveals a lack of studies making a direct comparison between outcome in the two patient groups.

### **Problems with existing studies**

Review of the literature has revealed that most studies of outcome following TBI have focused on those with severe initial injuries. Studies of minor TBI have been reported, although relatively less frequently, considering the much higher incidence of minor injuries. However, very little work has centred on those with moderate TBI, and that which has, has advocated a need for further research concerning the long term outcome of these patients.

The need for further research on moderate TBI patients was highlighted by Rimel et al. (1982) and again by Vollmer and Dacey (1991). Rimel et al. commented that patients with moderate TBI suffered 'substantial morbidity intermediate between ..... severe and minor head injury' at follow-up 3 months post-injury. Vollmer and Dacey emphasise the importance of studying less severe injury because of the incidence of these injuries and the likelihood of neuropsychological impairment. Despite this, studies have continued to focus on severe TBI, although occasional reports have appeared in the literature. McMillan and Glucksman (1987) investigated neuropsychological outcome in patients with moderate TBI but the criterion used for severity of injury was a PTA of 1 - 24 hours. As they themselves comment, this would usually be classified as a mild TBI.

Another study, investigating moderate and severe TBI, used the criteria of GCS 3 - 8 within 24 hours of injury and/or a PTA of at least two weeks, both of which are usually taken as indicative of severe or very severe injury (Dikmen et al. 1993). Whilst Kreutzer et al. (1993) looked at outcome in patients who were GCS 3 - 12, no distinction between moderate and severe TBI was made.



Few studies exist which compare groups based on severity. Uzzell (1987b) made one such comparison of severe versus mild TBI, but the selection criteria she used resulted in 54 patients being tested from a series of 142, with only 43 patients being suitable for inclusion in the comparative analysis: 21 mild and 22 severe.

Correll et al. (1993) looked at the performance of CHI patients on the sub-tests of the WAIS. The study was primarily aimed at investigating the level and pattern of functioning exhibited by the CHI patients during the acute stage of their injury by assessment on the WAIS, and to see if there was a typical pattern of performance. They found that patients with severe or moderate CHI were significantly impaired relative to the mild CHI patients, but did not differ significantly from each other. These findings are slightly surprising, but may be at least partially explained by the methodology of the study. Although assessments were carried out during the acute admission period, the timing of assessment varied, (mean interval between injury and assessment 19.6 days; S.D. 17.8), and was likely to be dictated to some extent by the inclusion of the selection criterion 'able to complete the entire WAIS'. The data from the moderate and severe patients may reflect a 'floor' effect, in that the levels of performance by both patient groups may represent the lowest level of functioning at which it is possible to complete the WAIS. The report fails to give details of any patients who were unable to complete the assessment, and the study sample may well be biased.

Another study to have compared groups of moderate and severe TBI reports a slightly higher proportion of poor outcome in the severely injured group at six months post-injury (Anderson et al. 1994). However cognitive assessment revealed no difference between patient groups on any of the tests used. These results reflect a similar finding to that of Correll et al. (1993).

Although it is expected that moderate TBI patients would experience some cognitive impairment the results of Correll et al. and Anderson et al. were somewhat unexpected.

One of the main methodological problems when considering reports of outcome following TBI is that a majority of studies use very stringent selection criteria, such as no past history of drug or alcohol dependency, with the net result that findings are specific to a very skewed sample of the severe TBI population. Although there are often plausible reasons for using such criteria, the incidence of drug and alcohol dependency is high in the TBI population, and the outcome of these patients is an issue which should be addressed rather than dismissed.

Few studies have investigated outcome in a consecutive series of patients in order to overcome sample bias: one report investigated the neuropsychological characteristics of patients who were GCS 3 - 12, but timing of baseline neuropsychological assessment varied from 2 to 260 days post-injury (Kreutzer et al. 1993); whilst another reports outcome in consecutive admissions to a rehabilitation facility (Ponsford et al. 1995a). As rehabilitation was restricted to patients sustaining TBIs in either motor vehicle accidents or work-related accidents, this in itself leads to sample bias. Other studies report outcome in consecutive patients but with strict selection criteria including no history of pre-existing conditions such as alcoholism or psychiatric disorder (Dikmen et al. 1993) again leading to sample bias. This suggests a need for a systematic investigation of outcome in a representative sample of patients.

Another problem with many studies of TBI is that they report outcome over the first six months or one year post-injury only. Obviously, there are likely to be temporal and financial constraints on any study, but this focus on early recovery has detracted from studies of later outcome. Studies have shown that patients can continue to recover for many years, and can deteriorate: by restricting studies to the early stages post-injury there is a possibility of missing late improvements or deterioration in the patients' outcome. Other studies consider patients at various times post-injury as a single group, again hampering interpretation by confounding variables.

The majority of outcome studies of SAH reported in the literature have investigated outcome in patients who were WFNS Grade I or II at admission. This leads to an immediate and misleading bias. If poor grade patients are excluded from the study, then any investigation of outcome will be skewed toward the 'better' end of outcome in the population as a whole. A related difficulty which arises in comparing studies is that different inclusion criteria are often used. Some studies have considered surgically treated patients only (Gotoh et al. 1996) whilst others have looked at 'good recovery' patients only (Ljunggren et al. 1985), or patients with aneurysms at specific sites (Rinne et al. 1996).

The length of time since operation to follow-up varies considerably in many reports of outcome following SAH. This may be acceptable, or it may prove to be a confounding factor depending on the aims and objectives of the study. If recovery continues for a prolonged period of time, as has been suggested, then this may have implications for a study where the follow-up interval is broad.

The present study set out to address some of these methodological problems, and the design of the study shall now be described.

## Chapter Three      Study Methods

### 3.1 Design of the Study

The present study was set up to carry out a more thorough investigation of outcome following moderate or severe TBI in a group of consecutive patients drawn from the same population. A group of SAH patients was also included because similarities between acute brain injury resulting from TBI or SAH have been noted, but reports of a direct comparison of outcome are very few.

The aims of the study were:

- to enable comparison of outcome after moderate or severe TBI, or SAH;
- to enable comparison of cognitive impairment following moderate or severe TBI, or SAH;
- to enable comparison of the nature of changes as reported by patients' relatives;
- to follow recovery over time.

In designing the study, there were several factors which influenced the methodology and which needed to be taken into consideration.

#### **Admission to the Regional Neurosurgical Unit**

Patients with moderate or severe TBI, as determined by GCS on admission, are routinely transferred from referring hospitals to the regional neurosurgical unit (RNU) for surgical treatment or conservative management and observation on a neurosurgical ward. Therefore, the study was limited to those patients who sustained a moderate or severe TBI, drawn from the same population and who received treatment in the same RNU.

With regard to SAH, the policy is to transfer all patients with suspected SAH to the RNU irrespective of the grade (O'Sullivan et al. 1996). For this reason, a group of patients who were admitted consecutively to the regional neurosurgical unit with a diagnosis of aneurysmal SAH, were entered into the study. This will overcome the flaws of some other studies which do not admit poor grade patients, thereby inflating their survival rates and estimate of levels of patient outcome.

#### **Severity of Injury**

The GCS is the most widely accepted index of severity of TBI used at the time of injury. Many studies of TBI have identified patient groups on the basis of their GCS (Rimel et al. 1982; Barth et al. 1983; Levin et al. 1990; Choi et al. 1994), and by using such a standard

measure, comparisons can be made between studies. Another advantage of using GCS is that patients can be identified at the time of hospital admission for prospective entry into a study.

The current study used GCS on admission to identify patients prospectively who were suitable for the study. The admission policy of the RNU was such that minor TBI patients were not routinely admitted, so the study was restricted to those with moderate or severe injury based on their GCS scores.

In addition to this, PTA was estimated retrospectively by questioning patients about their first memories following the accident, and the time when they considered they had regained consciousness and were able to remember details from one day to the next. This was clarified by discussion with the relatives. This method is inherently less accurate than prospective measurement of PTA (Forrester et al. 1994), but it was felt to be adequate for the present purpose. However, it has been shown that for more severe injuries retrospective assessment of PTA is valid (McMillan et al. 1996).

The present study was primarily intended to follow the pattern of recovery in patients with moderate or severe TBI, so timing of assessments was planned to be at six, 12 and 24 months. These time intervals were thought to be appropriate when considering the severity of injury and the nature of assessment, and have also been used by some other workers (Oddy and Humphrey, 1980; Fearnside et al. 1993). In order to optimise attendance rates, the duration of assessment was a maximum of 1.5 hours in accordance with the recommendation of Clifton et al. (1992), and where necessary, patients were seen in their own home.

## **ASSESSMENT METHODS**

### **Fixed Test Batteries**

A fixed battery of tests can be defined as a selection of tests which remains constant from one subject to another (Russell, 1994). Test batteries were developed as a result of efforts to standardise clinicians' assessment techniques and procedures. There are two types of fixed test battery: comprehensive batteries, aimed at assessment of a broad range of function; and specialised batteries, aimed at detailed assessment of a specific type of function (Goldstein, 1987). The selection of tests for inclusion in a battery is dependent on the purpose for which it is developed: through systematic use it helps to provide constancy from one assessment to the next.



The long-standing controversy over the advantages of fixed versus flexible batteries for clinical purposes is not relevant here. Fixed batteries are particularly appropriate for research studies, whereby the constancy of data collected is of paramount importance. Any study which involves a comparison of two patient groups must use the same measures for both. The same procedure is used to administer the same tests to all patients, enabling direct comparison to be made between two groups of patients. Therefore, a fixed test battery is the best tool for research studies.

A neuropsychological assessment was proposed which covered areas of functioning which are known to be commonly affected by brain injury. There were a number of constraints which limited the tests for inclusion in the assessment. These constraints fall naturally into two types: those which relate to the overall assessment battery, and those which relate to the individual tests.

### **Requirements of a Test Battery**

A battery of tests should be suitable, practical and useful (Lezak, 1995). It must be appropriate to the patients for whom it is designed. If the battery is to be used with an unselected group of patients, as in the present case, then it must be broad enough to provide some data on all major aspects of cognitive function. Ideally, it should be easy to administer and portable as some patients may need to be seen at home. In addition to this, it should not leave the patient feeling anxious or exhausted.

There are a number of widely used standard test batteries available, as reviewed by Lezak (1995), but these are either limited in their assessment of aspects of functioning commonly affected in head injury or too long. Examples of those batteries which are restricted to assessment of some aspects of functioning include the Wechsler Memory Scale (Wechsler, 1945; Wechsler, 1987), and those which may be classified as domain specific, including language batteries such as the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1972). One extreme example of a long test battery is the Halstead Russell Neuropsychological Evaluation System (HRNES) (Russell and Starkey, 1993) which includes the Wechsler Adult Intelligence Scale Revised (WAIS-R) (Wechsler, 1981), the Halstead-Reitan Battery (HRB) (Reitan and Wolfson, 1993) and an additional 12 tests. The time taken for a 'healthy young adult' to complete the HRNES has been estimated at about 10 hours (Lezak, 1995), with most patients taking longer.

In the present study, the recommendation of Clifton et al. (1992) that the duration of assessment be kept to 1.5 hours maximum was adopted. As this was a longitudinal study

with voluntary participation it was hoped that patients would attend assessments on three different occasions. If the first session was long and arduous it was less likely that the patients would return for their subsequent appointments.

Related to this was the restriction that assessments should be completed in one test session. The neurosurgical unit is based in Edinburgh but it covers a large catchment area. This meant that a number of patients needed to travel considerable distances to attend appointments and many needed assistance to get to the hospital because of the limitations of public transport. Thus it was important that assessments were completed in one session at each time period. A study by Uzzell et al. (1987a) included extensive neuropsychological assessment which lasted 'about four hours'. In order to maintain concentration, patients were tested during short time intervals over a period of several days. However, 22 of the 54 patients were in-patients at the time of assessment, making this a relatively feasible method of assessment. For practical reasons, it was not possible to adopt such a practice in the present study.

### **Disadvantages of Test Batteries**

Although these batteries may provide a very detailed picture of a patient's impaired and intact cognitive functions, there are a number of disadvantages associated with their use as a means of assessment. The main criticisms are the rigidity of this method which can lead to excessively time-consuming and inefficient assessment (Goldstein, 1987).

One of the more obvious disadvantages in using a battery of tests, is that of the time taken for the patient to complete the tests. This may vary greatly between patients, depending upon the severity and nature of their impairments.

Another disadvantage of using a test battery is that the tests used may omit assessment of a particular area of cognitive functioning. For these reasons a battery was developed specifically for the study.

## **3.2 Development of the Assessment Battery**

A considerable number and range of tests have been used to assess cognitive impairments within the brain-injured population. Therefore, there was a need to choose measures which were well-tested with established reliability and validity, and which were known to be sensitive to the effects of the brain injury. Because of the vast range of cognitive functions which *could* be affected by damage to the brain, the test battery needed to be focused toward the investigation of functions most commonly noted following head injury, such as memory,



concentration and information processing. The battery comprised a series of tests with established validity and reliability, and which are commonly used in clinical practice to assess cognitive functioning.

Another criterion included in the test selection was that normative data were available for the tests. This enabled a comparison to be made between the performance of the brain-injured patients and their 'expected' performance based on an estimate of their pre-morbid level of functioning.

The tests chosen were intended to be not too difficult for patients to attempt, nor so easy that the patients performed at 'ceiling' making the tests unable to reflect any improvement in performance over time. This is not an easy criterion to achieve when considering the wide variability in the patients' pre-morbid level of functioning, and broad range of the extent and nature of impairment after injury.

Prior to any formal cognitive assessment it was necessary to check that the patient was oriented, and that their performance on the assessment would not be affected by the presence of a language disorder.

## **ORIENTATION**

Loss of orientation, particularly in time and/or place, is frequently associated with brain injury. Orientation is dependent on continuity of awareness and translation of immediate experience into memories. Orientation in time and place is important in determining the end of PTA. Patients who have sustained a severe TBI may experience a PTA which can last for many months.

### **Temporal Orientation Test (TOT)**

The Temporal Orientation Test (TOT) used by Benton et al. (1964) was chosen for inclusion in the test battery. It is a standard procedure whereby the patient is asked to give the day, date and approximate time without consulting a diary, calendar or watch. An error score is obtained on the basis of the patient's reply.

A total error score is obtained by summing the error scores on each of the five elements of the test.

**Table 3.1          Scoring system for the Temporal Orientation Test (Benton et al. 1964)**

Error Points	Answer
1 (up to maximum of 15)	Each day of the month
5 ( up to maximum of 30)	Each month
10 (up to maximum of 60)	Each year
1 (up to maximum of 3)	Each day of the week
1 (up to a maximum of 5)	Each 30 min. from correct time

This total error score is then classified according to the following scale.

**Table 3.2          Classification scale for the Temporal Orientation Test (Benton et al. 1964)**

Total Error Score	Classification
0 - 2	Normal
3	Borderline
4 - 7	Moderately Defective
8+	Severely Defective

Benton et al. report that the most common errors, in both control subjects and brain-injured patients, was to mistake the date i.e. the number of the day of the month. The other commonly occurring error for both groups was in estimation of the time of day to within half an hour of the correct time. A difference arose between controls and brain-injured patients in that those with brain injury were much more likely to misreport the correct day of the week than the control subjects (Benton et al. 1964).

## **LANGUAGE FUNCTIONS**

Many patients who sustain a brain injury will show signs of language impairment. There are many ways in which language functioning can be affected, some of them more disabling than others. For example, it is relatively common for patients to experience word finding difficulties but because of the amount of redundancy in our language it is often easy to overcome word finding problems by using alternative words or descriptions in everyday speech. However, some patients experience comprehension difficulties which can be much more disabling. Patients may be unable to follow anything more than simple commands, which presents problems when given instructions to do something.



A screening test was used at the beginning of the assessment session to indicate the presence of an aphasic disorder in the patient. It was important to ascertain whether the patient's comprehension and/or expression were impaired prior to asking them to undergo formal neuropsychological assessment.

### **Frenchay Aphasia Screening Test (FAST)**

The Frenchay Aphasia Screening Test (FAST) was developed by Enderby, Wood and Wade (1987), to provide a standard method for doctors and clinicians to estimate the presence of an aphasic deficit. The term 'aphasia' is used by the authors to denote any language disturbance.

The FAST addresses four areas of language which may be affected in an aphasic patient: comprehension, expression, reading and writing. The FAST provides a score out of 10 for comprehension and expression respectively, and a score out of 5 for reading and for writing. An overall test score (out of 30) may also be used by summing the component scores.

The FAST can be abbreviated by omitting the reading and writing items, without loss of validity or reliability. Most aphasic patients have some disturbance of comprehension or expression and so these two aspects of language are most central to an assessment of aphasia (Enderby et al. 1987). An overall score out of 20 can be used by combining the comprehension and expression scores. This abbreviated form was believed to be adequate for the purpose of screening patients in the present study for any aphasic disorder.

#### *Comprehension*

The assessment of a patient's comprehension is addressed by giving a total of 10 instructions of graded linguistic complexity, relating to two cards. The first card is of a river scene, and the second card shows five shapes. The instructions begin with simple commands, such as 'Point to the square', and progress to complex commands, such as 'Before pointing to a duck near the bridge, show me the middle hill'. There are five instructions for each card, and the patient is given one point for each instruction correctly executed.

#### *Expression*

The assessment of expression entails asking the patient to describe the river scene depicted on the first card. They are then given a score in the range of one to five on the basis of their reply. For example, a reply consisting of the names of three or four items would be scored two, whereas a maximum score of five requires the use of words and phrases including the



names of at least ten items. Patients are then asked to name as many animals as possible in 60 seconds. Again, they are given a score from one to five depending on the number of animals named. For example, three to five animals named would give a score of two, and 15 or more would score a maximum of five.

There are a number of advantages associated with using the FAST as a screening test. One of the most important is that it can be used reliably by professionals other than speech and language therapists. It has also been shown to be sensitive in identifying patients with aphasia, and it is easy and quick to administer.

The authors conclude that the FAST may be useful in three different ways:

- as a screening test to identify any language disturbance following a known brain injury;
- for use as a research tool to identify patients with aphasia, where the administration of subsequent tests is reliant on adequate language function;
- to monitor recovery in unselected patient groups by repeated assessment (Enderby et al. 1987).

Few accounts of the use of the FAST have been reported in the literature. However, O'Neill et al. (1990) report its use in an elderly community population and in a group of stroke patients. They found that the FAST is sensitive in accurately detecting aphasia in patients with language disturbances, but it is not specific in that it is inaccurately suggesting aphasia in some patients without evidence of disturbed language. Based on their data from the community population, the authors recommend that the cut-off level of 25/30, suggested in the test, is amended and that a score of 23 or lower is used to denote the presence of aphasia. The data also show a correlation with age, and O'Neill et al. recommend caution in the interpretation of scores just below the cut-off point in the assessment of very elderly patients.

Although these data question the original norms used in the FAST, it should be remembered that O'Neill et al. were using the test with elderly subjects and have shown a correlation between performance and age. In the present study, the patients were much younger, and the test was used as a screening tool to identify those with aphasic disorders. If the cut-off point is too high, then this will provide an over-estimate of the presence of aphasia. However, all true instances of language disturbances should be detected.

From this, it can be seen that the FAST is an ideal test for current purposes. Because of the need to keep the overall neuropsychological assessment as brief as possible, and because of

the adequate psychometric properties of both the full and shortened forms of the FAST, the shortened form was believed to be adequate for present purposes.

### **Naming to Confrontation**

One of the most commonly reported sequelae of brain injury is difficulty in word finding. This phenomenon is familiar to everyone, in cases where we know the name we need to use, but are unable to retrieve it from memory, and the name is described as being on the 'tip-of-the tongue'. In people with word finding difficulties, the frequency of the tip-of-the-tongue state is much higher, often leading to irritation and increasing frustration. In everyday speech it is often possible to overcome such naming problems by using other words or descriptions, but name retrieval problems are more easily elicited on naming to confrontation tasks (Heilman et al. 1971). The frequency of patients' reports of word finding difficulties led to the use of a naming to confrontation test to identify the presence of a naming difficulty or anomia.

### **Boston Naming Test (BNT)**

The Boston Naming Test (Kaplan et al. 1983) was selected for inclusion in the test battery. The test comprises a set of 60 line drawings presented consecutively, beginning with highly familiar items such as a bed and a comb, and progressing to low familiarity items, such as an easel and a protractor. The subject is shown one picture at a time and asked to name it. The score used here is simply the number of items correctly named.

Normative data for the BNT show that there is little age-related decline in scores until the late 70s, making it suitable for use with people of a wide age range. The increase in standard deviation of scores of people in their 60s and over suggests that there is a greater range of scores in the older population.

The BNT has been shown to be a sensitive indicator of naming impairments in people with a variety of neurological deficits, ranging from stroke to multiple sclerosis. Its sensitivity has led to its use as a repeated measure to monitor the degree of deterioration in dementia patients (Storandt and Hill, 1989). In addition to this, it has been shown to reflect word finding difficulties in patients following mild head injury (Lezak, 1991), and to indicate naming problems in children several years after severe TBI (Jacobs et al. 1995).

Perhaps the biggest disadvantage of the BNT is that it is not a British test, and there are differences in vocabulary between US English and British English. However, the tests are

being used to compare performances between groups and any effects of this should be evenly distributed between groups, and over time.

## **MEMORY FUNCTIONING**

Memory is widely accepted to be one of the most commonly affected cognitive functions following TBI (Newcombe, 1982; Brooks, 1990) and SAH (Larsson et al. 1989). Typically long term memory is most severely affected, with difficulties in acquiring new information and recalling it after a delay of minutes to weeks.

### **Verbal Memory**

A long-established and reliable method of assessing long term memory is the story recall task. This method of assessment of verbal memory has been used many times with the TBI population and has been shown to be a useful indicator of the presence of verbal memory impairment (Newcombe, 1982) even though difficulties with concentration and language comprehension may contribute to poor performance on the task.

### **Story Recall**

The story recall task is a sub-test of the Wechsler Memory Scales (WMS) (Wechsler, 1945; 1987). Although two stories are used in the WMS, in the current study the procedure used was for the experimenter to read out one passage only. The subject was then asked to recall as much of the story as they could immediately after presentation, and then after a 30 minute delay. The passages used were from the original Wechsler Memory Scale.

The main advantage of using a story recall task is that it has been shown to be a good indicator of verbal memory function (Brooks, 1976; Newcombe, 1982). The use of only one story per assessment enabled the stories to be used alternately at different intervals, thereby reducing practice effects. This method of using 'parallel forms' of a test is an established procedure, to reduce the likelihood of improvement caused purely by practice of the task alone. The 'Anna Thompson' story was used at 6 and 24 month follow-up assessments and 'The American liner' story at the 12 month assessment. If the same people had attended all three assessments it would have been possible to counterbalance the order of stories used so that half of the patients received one and half the other. However, it was thought to be methodologically safer to use the same story at 6 and 24 months and the alternative story at 12 months.

The main disadvantage of using this particular version of story recall lies in the consistently reported difference in difficulty between the two stories (Iverson, 1986; Henry et al. 1990).

This complicates interpretation of change over time to some extent. However, the choice of use of these stories was influenced by the fact that the revised Wechsler Memory Scale (WMS-R) (Wechsler, 1987) is used routinely in the Rehabilitation Unit, where a considerable number of patients had been treated, and were likely to have been assessed using the WMS-R. In order to minimise practice effects, it was desirable to restrict the number of times the patients were assessed on a particular test. In an attempt to limit patients' familiarity with specific stories, the passages used in the current study were taken from the original Wechsler Memory Scale (Wechsler, 1945) on which they were unlikely to have been assessed prior to this.

### **Visual Memory**

In order to assess visual memory, it is necessary to use a design or figure which is not susceptible to verbal coding. If a design is used which can be described verbally, then the verbal description may be used as an aid to memorising the visuo-spatial design.

### **Complex Figure Test (CFT)**

The method used was for the patient to be presented with a complex figure, and asked to copy it. On completion, the original and the copy were removed and the patient asked to draw it again 'from memory' without warning. The copy and recalled figures were then scored by breaking them down into 18 components, with each component scored separately: two points if complete and correctly placed; one point if either complete or correctly placed; and ½ point if incorrectly placed and incomplete (Loring et al. 1990). Both copy and recall have maximum scores of 36.

In order to minimise practice effects, two complex figures were used in the study. At the six and 24 month assessments the Rey-Osterrieth complex figure (Rey, 1941) was used, and at 12 months the Taylor complex figure (Taylor, 1979) was used.

Some studies have used two recall trials, immediate and delayed, with the duration of delay varying from 20 minutes to an hour. However, the duration of delay up to an hour has been reported to make little or no difference to the person's performance (Lezak, 1995). The addition of a delayed recall trial was believed unnecessary in the present study as it would give little additional information for the extra time taken.

There are one or two drawbacks in using the CFT with the present patient population. A number of patients experienced motor problems as a result of their brain injury, which meant that some were unable to perform the task. Another problem is that the strategy by

which people copy the figure is important in determining how well they recall the figure. Brain injury is known to affect planning and organisation, and this may well impact on their performance on the CFT. At 12 and 24 months some patients, but not all, will remember that they will be requested to draw the figure from memory. This may also contribute to the variability in test scores.

## **CONCENTRATION**

Concentration problems are frequently reported following TBI of any severity (Dikmen et al. 1986; Hugenholtz et al. 1988). These have an important bearing on everyday life: poor concentration is likely to affect the person's ability to work as well as their social and leisure activities.

### **Trail Making Test (TMT)**

The Trail Making Test (Armitage, 1946) was developed for use by the U.S. Army in 1944, and amended by Armitage (1946). It is a test of visual conceptual and visuomotor tracking comprising two parts, A and B (hereafter referred to as TMT-A and TMT-B). It has been shown to be sensitive to frontal lobe damage (Parkin and Leng, 1993), and is often used as a test of concentration.

In part A, the subject is required to connect a series of circles, numbered from 1 to 25, as quickly as possible without removing the pencil from the paper, in numerical order. In part B, the subject is required to connect 25 circles, each containing either a number between 1 and 13, or a letter between A and L as quickly as possible without removing the pencil from the paper. However, the subject's task is to connect circles in sequence alternating between a number and a letter. The subject is given a 'Sample' of 8 circles corresponding to part A, and a further 8 corresponding to part B, to ensure that they understand the test instructions prior to beginning the timed trial. The test is scored by recording the times taken to complete parts A and B. Any mistakes made by the subject are corrected by the examiner as the subject completes the task, and so are reflected in the length of time taken to complete the task. This method was introduced to simplify the scoring procedure but it has been criticised because it is likely to lead to a lack of reliability in the data (Lezak, 1995).

One of the advantages of the TMT is that it is highly sensitive to the effects of brain injury, with performance on the test reported to be related to severity of injury (Leininger et al. 1990). It has also been shown to be predictive of level of independence achieved by a group of patients following moderate or severe TBI (Acker and Davis, 1989). Patients with



concentration difficulties and who are easily distracted often struggle on TMT-B, where they are required to keep track of two things at once.

Another advantage is the simplicity of the instructions, and the use of a sample trial prior to the test itself. Because of the motor component in the TMT, it is appropriate to look for impairment either by subtraction of TMT-A from TMT-B, or by calculating proportionate scores (Corrigan and Hinkeldey, 1987).

The argument that the scoring system used with the TMT can lead to lack of reliability in the data is a valid one. It was hoped that by using the same experimenter throughout the data collection that variability due to experimenter error would be kept to a minimum. However, it is valid to say that some patients were quicker to appreciate, accept and amend their errors than others. This may be a reflection of other cognitive difficulties which the patient is experiencing as a result of their brain injury.

### **Paced Auditory Serial Addition Task (PASAT)**

Another well-established test involving concentration is the Paced Auditory Serial Addition Task (Gronwall and Wrightson, 1974). This was developed as a task of information processing, requiring both speed and manipulation of information. It was first used for patients following minor TBI or concussion, and proved to be very sensitive to deficits in information-processing ability.

The task comprises a list of 61 single-figure digits, randomly ordered, and presented at a uniform rate. The subject's task is to add up pairs of digits, so that as each new one is presented, they add it to the last one they heard. For example, if the digits presented were 7 - 4 - 9 - 1 the subject's responses should be 11 - 13 - 10. Prior to beginning the test, a practice series of 10 items is given (and can be repeated) to ensure that the subject has understood the instructions. In order to ensure standardisation of presentation and to enable strict control of the rate of presentation, a pre-recorded tape is used.

The original version of the PASAT used four presentation rates of 2.4, 2.0, 1.6 and 1.2 seconds per digit. However, other workers have used slower rates of presentation (Levin, 1983 unpublished; cited in Lezak, 1995). The presentation rates used in the current study were 4.0 seconds and 2.0 seconds, in accord with Brooks et al. (1987b). The slower delivery rate was thought to be less stressful than the quicker rates used by Gronwall and Wrightson, although this led to the overall duration of that part of the test being longer.

Thus it was a test of sustained attention as well as ability to manipulate and process information quickly.

Reports of the use of the PASAT with patients following severe TBI suggest that they show marked and long term impairment in their performance on the test (Ponsford and Kinsella, 1992).

The biggest disadvantage of using the PASAT is that it can be very stressful for the subjects.

## **FRONTAL LOBE INJURY**

Frontal lobe injury is relatively common following TBI, and a similar site of lesion can be seen following ACoA aneurysm rupture. Its effects can be devastating so one of the few formal tests shown to be sensitive to frontal lobe damage was included.

### **Modified Card Sorting Test (MCST)**

Sorting tests are commonly used to assess patients for frontal lobe deficits. The Modified Card Sorting Test (MCST) (Nelson, 1976) was chosen as a simple version of the widely used Wisconsin Card Sorting Test (WCST) (Berg, 1948). The MCST uses the same four target cards as the WCST printed with the following: one red triangle; two green stars; three yellow crosses; four blue circles. The patients' task is to sort a pack of 48 cards, by matching them in some way to the four target cards. Each card is printed with between one and four of the four shapes in one of the four different colours, providing three different ways of sorting them: colour, shape or number. The subject is allowed to use any one of these rules at first and after six consecutive correct responses, (constituting one category), they are asked to 'find another rule'. Whichever new rule they choose is taken to be 'correct' and the procedure repeated. They are told whether they are correct after each card. When all three ways of sorting the cards are complete, they have to be repeated in the same order. The test is scored by recording the number of categories achieved (maximum of six), the number of errors made, and how many of these errors were perseverative. Errors are defined as perseverative if they use the same category concept as the preceding card which they have been told is incorrect.

Nelson (1976) reports the use of the MCST in a group of controls, and four patient groups: those with left frontal, right frontal, left non-frontal and right non-frontal damage. She found no difference between groups when comparing side of lesion, and the comparison between frontal and non-frontal groups just failed to reach significance, with the frontal lesion group performing more poorly. Both the frontal and non-frontal groups performed

significantly worse than the control group. From these results, it would appear that this particular card sorting test is sensitive to brain injury, with weak specificity for frontal lobe dysfunction.

The MCST has the advantage of being much shorter than the original version of the WCST, and less likely to cause distress in patients who are perseverating with the wrong category. The use of explicit instruction to 'find another rule' also reduces distress in that the subject is made aware of the change. However, it has been criticised in that the change of rule after only six consecutive correct responses may not be sufficient for frontal patients to develop a strong response set (Lezak, 1995).

## **ADDITIONAL TESTS USED**

### **Digit Span (WAIS-R)**

The Digit Span is a Verbal sub-test of the WAIS-R (Wechsler, 1981), and is a measure of attention span. It comprises two parts: Digit Span Forward and Digit Span Backward.

In Digit Span Forward, the experimenter reads out a series of digits at a rate of one per second, and subjects are required to repeat them immediately the experimenter has finished. The test starts with a sequence of three digits, and after two trials, progresses to four digits and so on. The test stops when the subject fails both trials of one sequence length, up to a maximum of nine digits.

Digit Span Backward follows a similar format, although the instructions are to repeat the digits in the reverse order. The test starts with a three digit example, and then two digit sequences, with two trials for each sequence length before progressing to the next sequence length. The test is discontinued when the subject fails both trials, up to a maximum of eight digits.

When used as part of the WAIS-R, a 'total score' is calculated with each trial correctly recalled scoring one point. However, the length of the maximum span recalled may be more useful (Lezak, 1995). The Digit Span is often considered a test of immediate memory, but forward Digit Span is more a test of attention. Digit Span Backward is more dependent on memory because it relies on ability to encode and store the forward span prior to reversing the order, and is more sensitive to neurological disruption (Kapur, 1988). Lezak (1995) cautions against combining performances on the two parts into one test score, as this assumes that the two parts measure the same thing. However, the two parts rely on different cognitive abilities, and are differentially affected by brain injury, with impairments resulting



from brain injury revealed on the difference between Digit Span Forward and Digit Span Backward.

The biggest advantages of the Digit Span are that it is quick and easy to administer. It is more sensitive to left hemisphere damage than either right hemisphere or diffuse injury. Patients with severe TBI have been reported to have reduced spans (Ruff et al. 1986). Nevertheless, Correll et al. (1993) found no significant difference between CHI patients and psychiatric controls, and Kreutzer et al. (1993) found that moderate and severe TBI patients' performance on the Digit Span Backward test revealed little impairment, suggesting that it is not sensitive.

### **Digit Symbol (WAIS-R)**

Digit Symbol is a Performance sub-test of the WAIS-R (Wechsler, 1981). Subjects are given a sheet with four rows of 25 blank squares, each one paired with a square containing a number between 1 and 9, in random order. Above the rows is a key showing each digit, 1 to 9, paired with a symbol, and the subjects' task is to complete as many of the blank squares as they can within 90 seconds by inserting the corresponding symbol. The first 7 items are used as practice items prior to the start of the 90 second time limit.

Digit Symbol has been shown to be very sensitive to brain injury irrespective of the site of injury, because it draws on such a wide range of cognitive functions. It is of no use in determining lesion site, but performance can be affected by even minimal damage. Correll et al. (1993) reported that the score on the Digit Symbol was the most depressed of all WAIS sub-tests in a group of CHI patients. The severity of damage is reflected in the amount by which scores are depressed (Lezak, 1995) making it a useful indicator of the extent of injury. Performance of severe TBI patients has been shown to improve over time but remained impaired relative to controls for over 13 months post-injury (Mandleberg and Brooks, 1975).

### **Block Design (WAIS-R)**

Block Design is a Performance sub-test of the WAIS-R (Wechsler, 1981). It is a spatial task, involving the use of red and white blocks to construct different designs. Each block consists of two red sides, two white sides, and two sides diagonally divided with one half red and the other half white. The first two trials involve constructing replicas of a construction made by the examiner, and the remaining seven involve constructions from printed designs. The first five trials use four blocks in a 2 x 2 arrangement, with a time limit

of 1 minute to construct each design. The last four trials use nine blocks in a 3 x 3 arrangement, with a time limit of 2 minutes to construct each design correctly.

Block Design is a frequently used test of visuospatial organization. It is reported to be sensitive to brain injury, in that any kind of brain injury is likely to lower a person's score (Lezak, 1995). It has been used in a number of studies of TBI (Levin et al. 1990; Correll et al. 1993), but the results of these studies suggested that Block Design was relatively resilient to TBI. It was incorporated in the present battery because of the need for a test of spatial construction, and because of its reported good psychometric properties.

### **PRE-MORBID ABILITY**

Formal assessment of patients following acute brain injury gives an indication of the patients' current level of cognitive functioning. However, one of the issues which should be addressed is how this differs, if at all, from their premorbid level of cognitive functioning. There is a large degree of individual variation in ability amongst members of any population, and this holds true for the brain injured population. Depending on premorbid ability and competence two patients may appear to have roughly equivalent cognitive abilities but have different levels of disability. Thus it is desirable to have some estimate of pre-morbid level of functioning (Russell, 1994).

### **National Adult Reading Test (NART)**

The National Adult Reading Test (Nelson, 1982) was used to estimate premorbid IQ as it measures a function indicative of intelligence and is relatively resistant to brain injury (Crawford et al. 1988).

The NART comprises a list of 50 words which have irregular pronunciation. It begins with more familiar words (e.g. chord, ache, depot) and progresses to low frequency, low familiarity words (e.g. syncope, campanile). The task is to read the words aloud and errors in pronunciation are recorded. Each incorrect pronunciation has an error score of 1 and the total error score is then converted into an estimate of premorbid IQ.

Crawford et al. (1988) used the NART with patients following closed head injury, and found that the patients' performance on the NART was unaffected as a result of the injury. One explanation for this is that the skill of reading is well-learned at an early age (in most cases) and is therefore relatively robust and resistant to brain injury.



## **MOOD DISORDERS**

Patients who have suffered head injury are often reported to display symptoms of mood disorder and changes in emotion and behaviour. This may take the form of emotional lability whereby they demonstrate heightened emotions and sudden mood swings, or alternatively they may show little affect or be emotionally 'flat'. Reports of the prevalence of depression following TBI vary from between 6 and 77% (Robinson and Jorge, 1994) although part of this variation is due to differences in the definition of depression. The prevalence of anxiety has been estimated at approximately 30% (Epstein and Ursano, 1994). These increased levels of anxiety and depression have also been reported to persist for long periods post-trauma (Morton and Wehman, 1995). The reason for these observed emotional disorders may be a direct result of injury to the brain affecting mechanisms of emotional control, or alternatively it may be a psychological response to the injury and its consequences.

There are a number of assessment scales which have been developed to measure mood disturbances. Beaumont (1993) reviewed a number of rating scales used to assess anxiety and depression. Many of these were not designed as diagnostic tools but for use in assessing severity of illness in patients with a prior diagnosis of anxiety or depression. In addition, several of them are lengthy and most have been developed to investigate anxiety *or* depression but not both. However, the Hospital Anxiety and Depression Scale (Zigmond and Snaith, 1983) was adjudged to be a suitable instrument for present purposes.

### **Hospital Anxiety and Depression Scale (HAD)**

The Hospital Anxiety and Depression Scale was devised by Zigmond and Snaith (1983) as a self-assessment mood scale. It was designed to assist in the diagnosis of anxiety disorder or depressive disorder (as opposed to sadness or demoralisation). The items are targeted at psychiatric symptoms, and the scale largely avoids items which are likely to be affected by physical illness or impairment.

The HAD consists of 14 statements, seven relating to anxiety and seven to depression. Each statement is accompanied by four replies on a scale of severity, and the subject is asked to select whichever answer best describes how they have been feeling over the last week. Each of the possible four replies for each statement has a score of 0, 1, 2 or 3. A sum total is calculated for the seven items relating to anxiety, and likewise for depression. For each subscale, a sum score of 0 to 7 is normal, 8 - 10 is borderline, and 11 or more classified as

indicating a clinical disorder. The task itself is straightforward, and most patients have no difficulty in completing the questionnaire.

The HAD enables the distinction in diagnosis to be made between depressive and anxiety disorders, and its validity and reliability have been well established (Snaith and Taylor, 1985). Another advantage of using the HAD with brain injured patients is that it is short and easy to complete. Dowell and Biran (1990) carried out a postal study of general practice patients using the HAD, and obtained a return rate of 84%. This is high for a postal questionnaire leading them to conclude that patients would readily complete it.

Five of the seven items in the depression subscale are aimed at assessing anhedonia, believed by the authors to be a central component of depression. Although Zigmond and Snaith tried to exclude items which could be related to physical illnesses rather than symptoms of a mood disorder, in some cases the questions are open to the influence of physical difficulties or limitations, such as the statement "I feel as if I am slowed down" and the statement "I still enjoy the things I used to enjoy". In general, the items in the HAD which are most open to this criticism are those concerning depression. The items which are used to look at anxiety are more specific in that they relate more directly to typical symptoms of anxiety, for example, "I feel tense or wound up", and "I get sudden feelings of panic".

### **HEAD INJURY SYMPTOM CHECKLIST (HISC)**

The Head Injury Symptom Checklist (Dikmen et al. 1993) was used to report symptoms typical of post-concussion syndrome (PCS). It comprises a list of 12 symptoms which are commonly reported following TBI. The patient is asked whether they have experienced each symptom over the preceding two weeks, and if so, whether or not this is worse than prior to their head injury. It was used with both TBI and SAH patients in the present study; there are similarities in some aspects of the two types of brain injury and it was believed that there would be some degree of overlap in the symptoms reported by both patient groups.

The twelve symptoms in the HISC comprise:

- Headaches
- Fatigue
- Dizziness
- Blurred vision

- Bothered by noise
- Bothered by light
- Insomnia
- Memory difficulties
- Difficulty concentrating
- Irritability
- Anxiety
- Loss of temper easily

Patients were questioned about each symptom in turn, unless they spontaneously described the symptoms. Similar checklists have been described by other workers (King et al. 1995).

### **INFORMATION FROM A RELATIVE OR FRIEND**

The value of obtaining a relative's opinion has been acknowledged in the literature, much of which has focused on the impact of the brain injury on the patient's family, methods of coping within the family and the resultant burden experienced. A relative's report can also give important information concerning the patient's psychosocial behaviour (Dikmen et al. 1993), and the way in which the brain injury impacts on the patient's everyday life. Reports of relatives and patients have been found to differ, especially with regard to the reported extent of emotional and behavioural change, leading Brooks (1991) to recommend using both views.

### **Relative's Questionnaire (RQ)**

The Relative's Questionnaire (Brooks and McKinlay, 1983) was developed as the basis of a semi-structured interview to help to standardise the collection of data from a relative or friend of the injured person. In the initial stages of its development, it comprised 90 questions concerning the patient's outcome, but was reduced to 62 items following testing of its reliability, with the least reliable items being discarded (Brooks et al. 1987a). It was chosen for the present study because it was developed specifically for use with TBI patients and was therefore felt to be best suited to reflect the problems of this population.

The RQ is given to a relative or close friend of the injured person, and is used to gain information on how the person is compared with how they were prior to their injury. Relatives are asked whether the patient has shown 'no change', 'rather worse since injury' or 'much worse since injury' for each of the items. The 62 items can be subdivided into the following eight categories:

- physical disability;
- language deficit;
- emotional disorder;
- dependence;
- subjective symptoms;
- memory deficit;
- disturbed behaviour;
- social behaviour/leisure.

Despite the widespread use of the RQ in head injury research, there is little published data available concerning its reliability and validity. Although it has been used as a postal questionnaire (Anderson et al. 1993), the only available reliability data concerns its use within a semi-structured interview. The inter-rater reliability quoted would indicate that the RQ is a reliable measure, but the methodology undertaken comprised two people sitting in the same interview room simultaneously recording the responses of a single relative.

In the present study, it was intended to use the questionnaire on three separate occasions, so it was essential to ascertain that the relatives' reports were reliable, so that any change in their answers on the questionnaire might be indicative of change in the person's functioning. In order to test this aspect of the questionnaire, a separate study was carried out to look at its test-retest reliability (Hellowell and Signorini, 1997a). Most items showed 'substantial reliability' and those with lower levels of agreement seemed inherently likely to be influenced by real change in the patients. The reliability study suggested that it was suitable for use as a postal questionnaire, and could be used to identify change in both TBI and SAH patients.

### 3.3 Method

#### **Subjects**

One hundred patients admitted consecutively with a diagnosis of severe or moderate TBI, and who survived their initial hospital admission, were entered into the study prospectively. The classification of severity of injury was based on the patients' GCS on admission to the RNU, or alternatively, if the patient was paralysed, intubated and ventilated, their last known GCS prior to this. Severe head injury was defined as a GCS of 3 to 8 with no eye opening, failure to give any comprehensible verbal response and failure to obey commands, in accordance with recommendations (American Congress of Rehabilitation Medicine,



1995). The category of moderate head injury was defined as GCS of 9 to 12 on admission, but expanded to include patients with a GCS of more than 12 but who required neurosurgical intervention, based on the findings of Williams et al. (1990).

A group of 44 SAH patients admitted consecutively to the RNU, and who survived their initial hospital admission, were entered into the study. This group comprised patients of all grades of SAH, as the admission policy of the RNU was that all suspected SAH patients were admitted and treated within the unit.

For all patients, basic demographic details were collected including age, sex, date of birth, occupation and cause of injury. Once discharged from the RNU, details of their stay in the RNU were recorded from their notes. Information included CT diagnosis, additional injuries, neurosurgical intervention, other operative treatment, intra- and extra-cranial complications, duration of admission, and destination upon discharge.

### **Procedure**

Traumatic brain injury patients were invited to complete the following tests and measures, as described in detail earlier, at six, 12 and 24 months after injury. Subarachnoid haemorrhage patients were invited to complete a slightly abbreviated battery.

- Benton Temporal Orientation Test (TOT)
- Frenchay Aphasia Screening Test (FAST)
- Boston Naming Test (BNT)
- Story Recall - Immediate and Delayed (from Wechsler Memory Scale)
- Complex Figure - Copy and Recall (CFT)
- Trail Making Test (parts A and B)
- Paced Auditory Serial Addition Task (PASAT)
- Modified Wisconsin Card Sort Test (MCST)
- Digit Span (from Wechsler Adult Intelligence Scale - Revised)
- Digit Symbol (from WAIS-R)
- Block Design (from WAIS-R)
- National Adult Reading Test (NART)
- Head Injury Symptom Checklist (HISC)
- Hospital Anxiety and Depression Scale (HAD)



In addition to the patient assessment, a close friend or relative of the patient was asked to complete a Relative's Questionnaire (RQ) (Brooks and McKinlay, 1983) as previously described.

The test battery was used with all TBI patients. The SAH patients were given a slightly abbreviated selection of tests by omitting the Boston Naming Test, Digit Symbol, Digit Span and Block Design tests from the battery. This was the only difference between assessments of SAH and TBI patients. All other procedures were identical for both groups. The main reason for the use of an abbreviated test battery with the SAH patients was that the assessment session had to be restricted to one hour, because of demands on the availability of rooms in the RNU in which to carry out the assessment. The inclusion of the SAH group was intended to enable tentative comparisons to be drawn, and to determine whether a full investigation of cognitive impairment and outcome following SAH was warranted. It was not the primary aim of the study and so had to fit in with other priorities within the study, and within the department.

Six months after injury, patients were invited to attend the Out-patient Department for a follow-up appointment. They were given an explanation of the purposes of the research, and told that they would be asked to attend again at 12 and 24 months post-injury, in order to follow their recovery over time. Participation in the study was voluntary and they were assured that they could withdraw from the study at any time without it affecting their medical care. Patients were required to sign a consent form if they were willing to participate in the study, and undertake assessment (See Appendix A). If patients had moved since discharge, efforts were made to locate them via their local Health Board, and if re-located, the same procedure followed.

Patients who agreed to take part in the study were then asked to undertake a formal cognitive assessment, and if they were accompanied by a friend or relative, the friend or relative was asked to complete an RQ whilst the patient was assessed. In cases where the patient was unfit for assessment, discussion involving the patient and relative was carried out to ascertain the extent and nature of the patient's difficulties.

The information gathered about the patient, from cognitive assessment and/or the RQ, was used as the basis for estimation of outcome using the GOS. In cases where the patient remained hospitalised or in long term care at the time of their follow up appointment, the patients were visited to assess their suitability for cognitive assessment. In most cases, these patients were unable to undertake formal neuropsychological assessment. Some were

very confused, whereas others were unable to understand anything more than a simple command which made formal assessment unsuitable because they were unable to understand the instructions. A GOS was assigned on the basis of their level of disability, and where appropriate, an RQ was left with relatives for completion and return in a pre-paid envelope.

Some patients refused to take part in cognitive assessment, but were willing to ask a relative or friend to complete an RQ. In these cases the GOS score was assigned on the basis of the RQ information only. However, some patients who were unwilling to undertake cognitive assessment were also unable or unwilling to provide questionnaire information. Sometimes the patient had no suitable relative or close friend to complete the questionnaire, but usually the questionnaires were not returned. For these patients, it was not possible to gather any direct information about their outcome, in which case a letter was sent to their GP asking them to assess the patient's outcome using the GOS.

All patients were sent further follow-up appointments at 12 and 24 months. The procedures used followed the same design as at the six month assessment time, enabling a comparison of results over time. The results of the follow-up assessments are now presented. Owing to the large number of multiple comparisons which are made in the analyses, only results which are significant at the  $p < 0.01$  level should be considered.

## Chapter Four Demographic and Acute Injury Data

This chapter will focus on the demographic information and acute injury data of patients entered into the study. It will follow the format of the thesis so far by considering the TBI patients, then the SAH patients, and finally a comparison of similarities and differences between the two.

### 4.1 Traumatic Brain Injury

The study was set up to investigate 100 patients who were admitted consecutively to the RNU, who survived the initial injury and were discharged from the unit.

Demographic data and acute injury information were collected from the patient case-notes. Of the 100 consecutive patients entered into the study, 53 were classified as having severe head injuries and 47 as having moderate head injuries. All of the patients had a recorded diagnosis of TBI but four patients (three male and one female), all classified as sustaining moderate head injuries, were later excluded from the study. One of them suffered a severe brain injury five months after his original moderate injury, confounding the effects of the initial injury. The other three patients were all diagnosed as having a fall causing a brain injury and admission to hospital. Following consultation with medical staff and close examination of the patients' notes and CT findings, it was concluded that they were most likely to have suffered a spontaneous intracerebral haemorrhage which had caused them to fall. Because the true nature of their brain injury was not clear they were excluded from the remainder of the study. Thus data are presented for the remaining 96 patients: 53 severe TBI and 43 moderate TBI.

The detailed acute injury and demographic information collected from the patients' medical notes included:

- sex;
- age at the time of injury;
- cause of injury;
- severity of injury;
- injuries sustained (head injury; additional injuries e.g. orthopaedic) and Injury Severity Score
- presence and type of skull fracture;
- Computerised Tomography (CT) scan diagnosis;
- operative treatment for head injury;

- intra- and extracranial complications.

These shall now be described and discussed in turn.

## SEX

Of the 96 patients included in the study, 76 were male and 20 female. The ratio of males to females was approximately equivalent in the severely injured group (3.81:1) and in the moderate group (3.78:1), and similar to that reported in other studies (Rimel et al. 1982; Bishara et al. 1992).

**Table 4.1      Severity of injury and sex of patients**

	Male	Female	TOTAL
Severe	42	11	53
Moderate	34	9	43
TOTAL	76	20	96

## AGE AT THE TIME OF INJURY

The patients in the present population ranged from 15 to 78 years old at the time of injury. Although there were no specific selection criteria to limit the age of patients, children who sustain TBIs are admitted to and treated in a children's hospital. The range in those with severe injuries was 15 to 78 years, and in those with moderate injuries was 16 to 72 years.

**Table 4.2      Mean and median ages of patient groups**

	Male		Female		Overall	
	Mean	Median	Mean	Median	Mean	Median
SEVERE	39	37	27	20	37	35
MODERATE	43	43	42	40	42	40

Table 4.2 shows the mean and median ages of patients by severity of injury and sex of patient. The mean overall age of the two groups of patients is not dissimilar, although the average age of females with severe injury is clearly lower than the other three groups. An unpaired t-test revealed no significant difference between groups ( $t = -1.615$ ;  $p = 0.110$ ).

## CAUSE OF INJURY

Road traffic accidents are widely reported to be the major cause of TBI, although there is some regional variability. In the present study they have been classified as pedestrian, car,

bicycle and motorbike rather than being grouped together. Taken as one group, they represent the most common cause of TBI in the present population. Table 4.3 shows the causes of injury in the present population.

**Table 4.3      Cause and severity of injury**

	Severe TBI		Moderate TBI		TOTAL
	Male	Female	Male	Female	
Fall	17	0	18	2	37
Pedestrian	8	4	4	1	17
Car	7	5	3	2	17
Assault	6	0	6	1	13
Bicycle	1	0	2	2	5
Motorbike	1	1	1	0	3
Jump	2	0	0	0	2
Riding	0	1	0	1	2
TOTAL	42	11	34	9	96

The most common cause of moderate injury was a fall whereas the most common cause of severe head injury was an RTA. This may be expected in that an RTA is likely to involve a much greater force than a fall.

**SEVERITY OF INJURY**

The severity of injury was measured in two ways: prospectively, based on GCS on admission, and retrospectively, using duration of PTA.

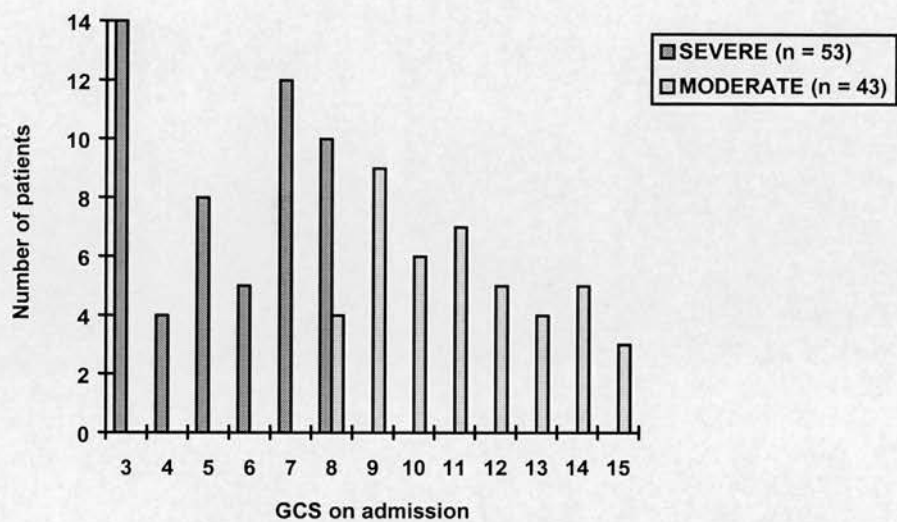
**Glasgow Coma Scale on Admission**

Glasgow Coma Scale on admission was taken from the patient’s notes. In cases where the patient had been transferred from an outlying hospital, and they had been paralysed, intubated and ventilated for transfer, the last known GCS prior to this was used.

Patients were assigned to either the moderate or severe group on the basis of their GCS. The distribution of patients according to GCS and classification of severity is illustrated in Figure 4.1.



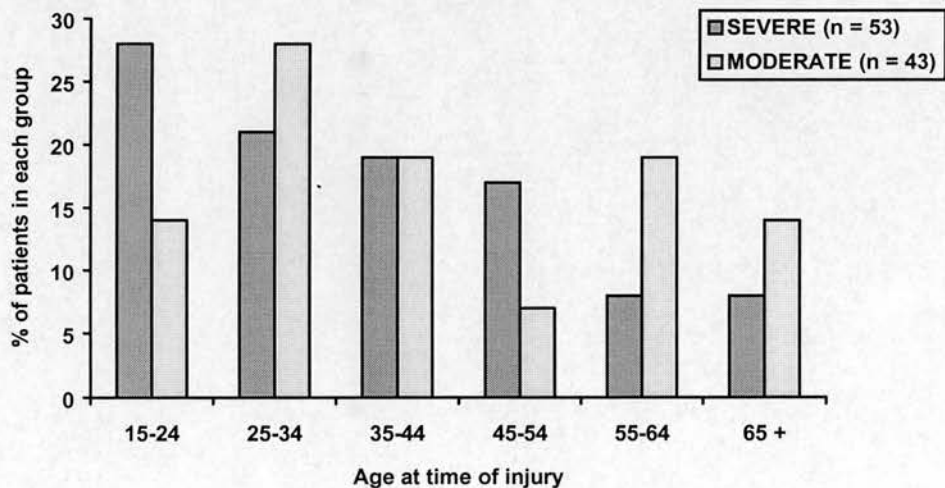
**Figure 4.1**      **Distribution of GCS scores on admission and classification into severe or moderate head injury based on GCS**



Severe head injury was defined as a GCS of 3 to 8 with no eye opening, failure to give any comprehensible verbal response and failure to obey commands. Moderate head injury was defined as GCS 9 to 12, or greater than 12 but requiring neurosurgical intervention (see Chapter 1; Section 1.1 for further details). Four patients with a GCS of 8 were classified as having ‘moderate’ head injury because they were either eye opening, providing verbal responses, or obeying commands (Levin et al. 1990; Jones et al. 1994).

The following graph, showing the distribution of age by severity of injury, reveals a different pattern between groups.

**Figure 4.2**      **The relation between age and severity of injury**



The incidence of severe head injury is highest in younger age groups, and decreases steadily in the older patient groups. The incidence of moderate injury peaks between 25 and 34 years, and then again between 55 and 64 years. This bimodal distribution has been found by other workers investigating head injury (Evans, 1994). It is partly caused by an increase in the incidence of falls in older patients, which tend to cause moderate rather than severe injuries. The difference in the patterns of distribution between groups is related to the different causes of injury: RTAs are more likely to cause severe TBI and are more common in young people.

### **Duration of Post-traumatic Amnesia**

Duration of PTA was determined retrospectively by questioning the patient and this was supported by discussion with a relative where possible. Patients were then allocated to one of four groups on the basis of duration of PTA, as follows:

- < 24 hours
- 24 hours - one week
- one - four weeks
- > four weeks

Duration of PTA was unavailable for six patients (four patients with severe injury and two with moderate injury as defined using the GCS). These were four patients who had died at the time of their 6 month follow-up, and two patients who refused to take part in the neuropsychological assessment part of the study.

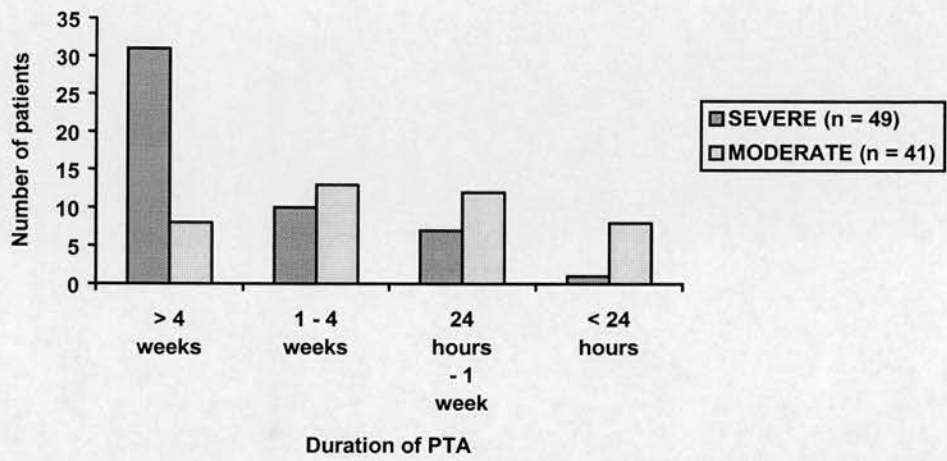
### **Post-traumatic Amnesia versus Glasgow Coma Score**

The use of GCS on admission enabled a grade to be given to all patients, whereas the duration of PTA was unavailable for six patients because of its retrospective determination in this study.

Longer durations of PTA are more frequent in patients with lower GCS admission scores although this is not always the case (Wilson et al. 1993). Duration of PTA is related to the type of brain injury as well as the severity, and patients with diffuse injury are more likely to have a longer PTA than those with focal damage (Smith, 1961). Other factors are also known to influence the level of consciousness and it may be the case that drugs or alcohol contributed to the reduction in some patients' GCS admission scores. The following figure shows the relationship between grade of severity based on GCS and the duration of PTA, illustrating that one patient with a low GCS score had a relatively short PTA.

The Spearman rank order correlation between GCS score and PTA category gave a value of  $r_s = -0.56$ ;  $p < 0.001$ .

**Figure 4.3**      **Duration of PTA in relation to severity and grade of injury based on GCS**



The PTA classification suggested by Jennett and Teasdale (1981) refers to PTA of 24 hours or less as moderate or mild, whereas duration of PTA longer than 24 hours is considered severe. Thus many patients classified as ‘moderate’ using admission GCS criteria would be classified as ‘severe’, ‘very severe’ or ‘extremely severe’ using the PTA grading scale.

Some patients who were graded as moderate on the basis of their GCS on admission may have suffered neurological deterioration or have had extracranial complications, contributing to their duration of PTA. In other cases, the length of PTA was likely to be due to a diffuse brain injury.

**Incidence of Alcohol and Drug Use**

It is well-established that many accidents which result in TBI occur when alcohol or drug use is involved. In the present study, there was often a comment about ‘alcohol on board’ in the patient’s medical notes, although there had been no alcometer reading taken or recorded. In some cases, there was no reference to the intake of alcohol, and in these patients it was unclear whether this was due to absence of alcohol intake, failure to record alcohol intake, or absence of information concerning alcohol intake. Thirty (57%) of the severely injured patients were reported to have been drinking alcohol, 15 (28%) were recorded as having had no alcohol, and the presence (or absence) of alcohol was not recorded in the remaining eight patients (15%). Of the moderately injured patients, 23 (53%) were recorded as having been drinking alcohol, 18 (42%) were reported to have had

no alcohol, and the information was missing in two cases (5%). These incidences are of the same order as reported elsewhere in the literature (Kraus and Nourjah, 1988; Vazquez-Barquero et al. 1992).

The use of recreational drugs was recorded in four severe and one moderately injured patient, with seven severely injured and six moderately injured patients reported to be on medication. Information on the use of drugs for recreational or medicinal purposes was missing for twelve severe and four moderately injured patients. It is likely that a small proportion of these patients were under the influence of recreational drugs at the time of injury.

**INJURIES SUSTAINED**

Other injuries were recorded according to part of the body which was affected, whether or not they required the opinion of another consultant, and whether or not an operation was required. Table 4.4 below shows the incidence and type of other injuries sustained by patients in the two groups.

**Table 4.4      Incidence of injuries and those requiring surgical intervention (in % per group)**

INJURIES	SEVERE (n = 53)		MODERATE (n = 43)	
	Injury	Operation	Injury	Operation
Head	100	81.1	100	55.8
Face	28.3	11.3	23.3	9.3
Neck	1.9	0	4.7	0
Thorax	30.2	3.8	20.9	2.3
Diaphragm	1.9	0	0	0
Abdomen/pelvic contents	20.7	18.9	2.3	0
Cervical Spine	3.8	1.9	0	0
Thoracic Spine	5.7	1.9	4.7	0
Lumbar Spine	7.5	1.9	0	0
Extremities/bony pelvis	49.1	26.4	20.9	7.0
Lacerations	71.7	15.1	60.5	4.7

This table shows that additional injuries were more common in the group of severe TBI patients. The only exception to this is injury to the neck, but the incidence was low in both groups. The biggest difference between groups is in the incidence of abdominal injury, or

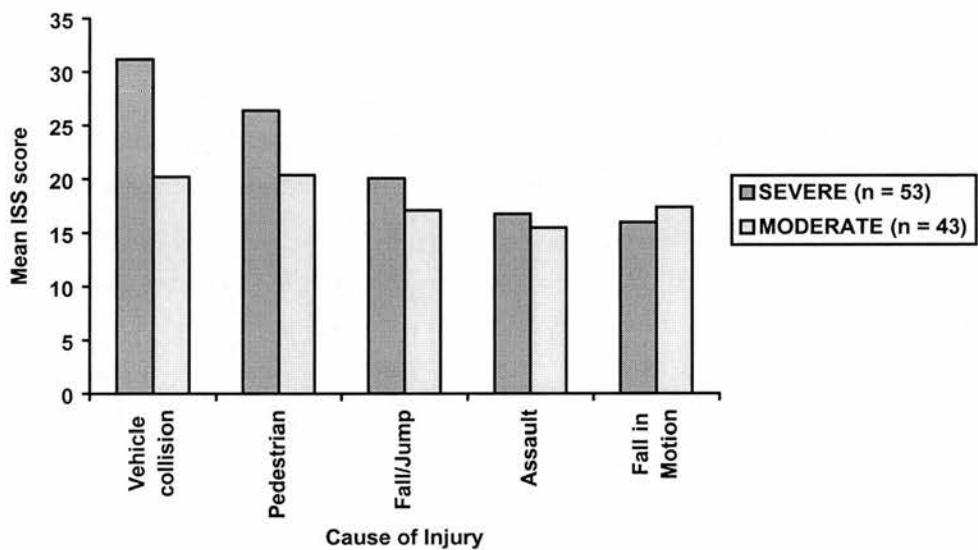


bony injuries such as fractured limbs and pelvis. Again, this is likely to be related to the cause of injury, in that RTAs are more likely to cause multiple injuries than falls.

**Injury Severity Score**

The ISS was recorded for each patient by an anaesthetist working in the ITU. It was expected that the ISS scores would differ according to the type of injury sustained, and also in relation to the severity of the TBI. The cause of injury was classified as either in/on vehicle in collision; pedestrian; fall; assault; or fall whilst in motion (e.g. riding; cycling). These classifications are used throughout the chapter, unless described otherwise. The distribution of mean ISS score according to cause of injury is shown below.

**Figure 4.4      Mean ISS scores by cause of injury and severity of TBI**



The mean ISS scores tend to be higher for patients with severe TBI, and are also higher for accidents involving motor vehicles. The highest mean ISS score occurs in the group of people who were travelling in vehicles involved in collisions and can perhaps be accounted for by the fact that the injuries are more likely to be sustained at high speed and therefore have a more serious impact. The safety features of vehicles and seat belt laws are such that low speed RTAs are much less likely to cause TBI.

The data also show very little difference in mean ISS score in the moderate group in relation to cause of injury.

Statistical analysis using Spearman rank correlation coefficient showed that correlations between ISS and severity of injury gave the following values: with GCS on admission



$r_s = -0.32$ ,  $p = 0.001$ ; and with PTA  $r_s = 0.45$ ,  $p < 0.001$ .

## PRESENCE AND TYPE OF SKULL FRACTURE

The presence and type of skull fracture was noted, and is reported in Table 4.5.

**Table 4.5 Frequency and type of skull fracture (number of patients)**

Type of skull fracture	Severe (n = 53)	Moderate (n = 43)	TOTAL
No skull fracture	20	17	37
Linear vault fracture	7	11	18
Linear basal fracture	13	8	21
Linear vault and basal fractures	10	5	15
Depressed fracture	3	2	5

The main difference between groups is the higher incidence of linear fractures alone in the moderate group, and a higher incidence of both linear vault and basal fractures in the severe group. This is likely to be related to cause of injury, and the higher incidence of multiple injuries in the severe group.

## PRIMARY DIAGNOSIS FROM CT EVIDENCE

The CT scan reports were used to provide the primary diagnosis concerning intracranial injury.

**Table 4.6 Primary CT diagnosis and severity of injury**

Primary CT Diagnosis	Severe (n = 53)	Moderate (n = 43)	TOTAL
Extradural haematoma	5	10	15
Subdural haematoma	17	11	28
Intracerebral haematoma	2	3	5
Contusions	10	14	24
Diffuse head injury	15	2	17
Depressed skull fracture	1	0	1
Closed head injury	3	3	6

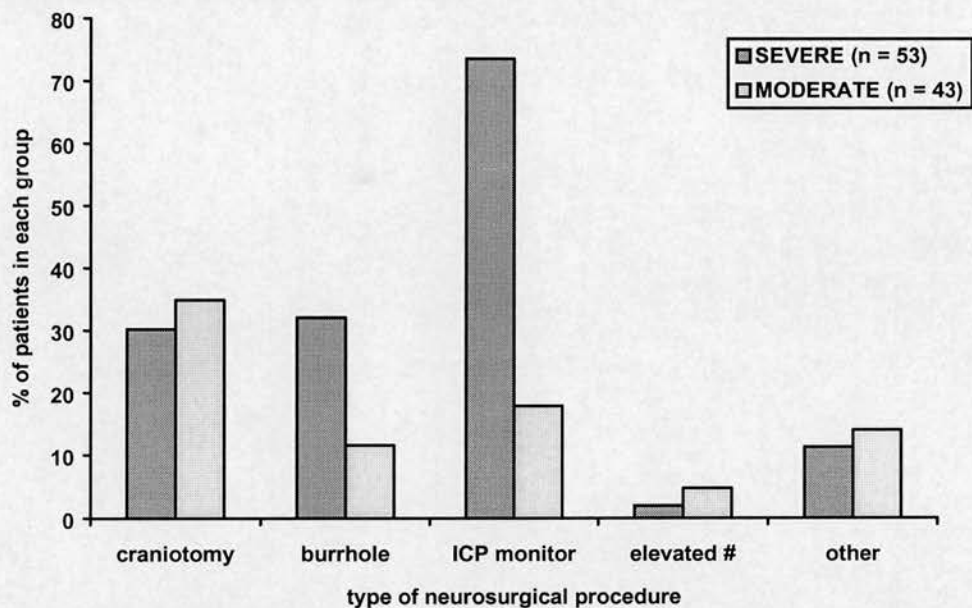
Some people had multiple injuries to their brain, and only the primary diagnosis given on their CT scan report is recorded here. In order for an injury to be classified as a 'diffuse head injury' it had to be described as such on the CT scan report. Diffuse damage may not

be observable on CT scans, and it is likely that many patients had some diffuse damage contributing to their overall injury.

**NEUROSURGICAL INTERVENTION**

A majority of patients in both groups required some kind of neurosurgical operation. The type of operative procedure was recorded, and any re-operation was also noted. Figure 4.5 shows the percentage of patients in each group and the type of neurosurgical treatment undertaken.

**Figure 4.5      Frequency of different neurosurgical techniques in both patient groups**



The category of ‘other’ includes patients who required treatments such as anterior fossa repair or insertion of a ventriculo-parietal shunt. Three patients in each group underwent a second burrhole operation for re-evacuation of a subdural haematoma.

The biggest difference between groups was in the use of an ICP monitor, which was much more common in the severely injured group. The ICP monitors are used to detect the presence of raised ICP, and this is more commonly associated with severe rather than moderate injuries. One reason which may account for part of the difference between groups is that the amount of equipment available for monitoring is limited, and where there is insufficient monitoring equipment for the number of patients it is likely that the equipment is used with the most severely injured patients.

### COMPLICATIONS

Specific complications were recorded, and scored for severity. These covered a range of neurosurgical, pulmonary, cardiovascular and other extracranial complications, selected on the basis of the experience of neurosurgical and ITU staff and included on a proforma sheet used within the RNU (Miller et al. 1992).

**Table 4.7      Range of complications recorded**

Neurosurgical	Pulmonary	Cardio-Vascular	Other
ICP >25mmHg	Infection	Shock	Peripheral vascular
Delayed haematoma	Embolus	Hypertension	Renal
Meningitis or	Insufficiency	MI or	Hepatic
Ventriculitis		CCF arrhythmia	
Hydrocephalus			Gastrointestinal
Seizures			Coagulopathy
Brain abscess			Electrolyte
CSF leak			Septicaemia
Wound infection			Diabetes

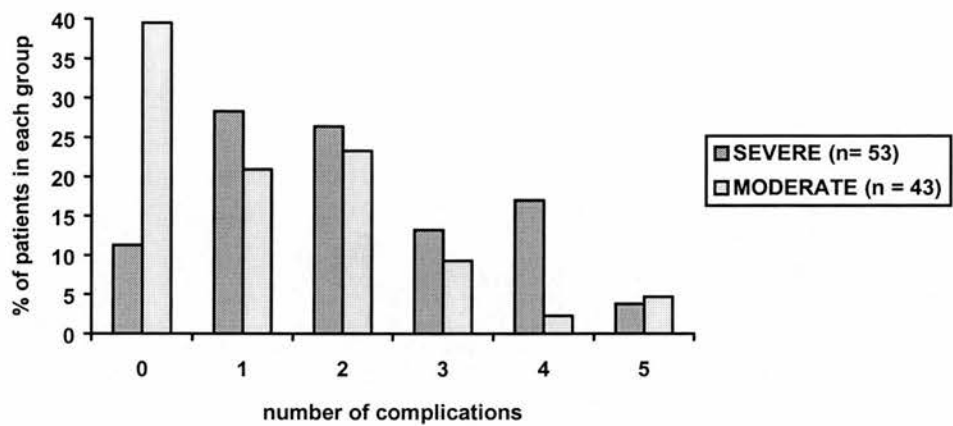
The complications were rated for severity by a Research Anaesthetist working with the ITU, using the following six point scale.

- 0 = no complication
- 1 = mild complication
- 2 = moderate complication
- 3 = serious complication - not life-threatening
- 4 = severe complication - life threatening
- 5 = cause of death.

Inevitably, no patient in the current study experienced a complication rated 5 as all patients in the study survived and were discharged from the RNU.

It can be seen that the incidence of complications was higher in the group of severe TBI than in the moderately injured group, as displayed in Figure 4.6.

**Figure 4.6      Number of complications in each group**



Investigation of the frequency of different complications revealed that the following were most common.

**Table 4.8      Numbers of patients suffering the most common complications following traumatic brain injury**

Complication	Severe (n = 53)	Moderate (n = 43)
Raised ICP	12	7
Delayed haematoma	2	6
Seizures	8	6
Pulmonary infection	34	12

In addition to this, the worst severity of complication for each patient was used to compare groups.

**Figure 4.7      Highest level of severity of complication experienced by patients in each group**

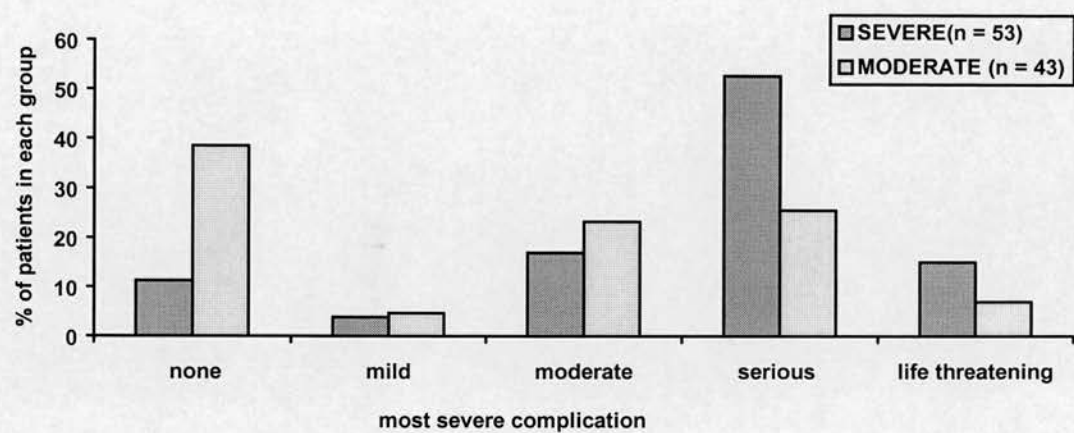


Figure 4.7 shows the difference between groups, with those in the severe TBI group more likely to experience more serious complications. Because many patients had more than one complication, a sum score was calculated for each patient and although the range was similar for both groups (0 - 16 for severe; 0 - 15 for moderate), the mean and median scores were higher in the severely injured group (mean 5.34, median 5; mean 3.14, median 2 for severe and moderate TBI groups respectively).

The different measures of complications correlated strongly with each other, suggesting that patients with the most severe complications were likely to be those with the greatest number of complications ( $r_s = 0.79$ ;  $p < 0.001$ ). The sum of severities of complications is inevitably related to the number of complications suffered, reflected in the degree of correlation between the two ( $r_s = 0.96$ ;  $p < 0.001$ ).

These findings show that patients with severe TBI are likely to experience more complications, of a more serious severity, than patients with moderate TBI. However, some patients with moderate TBI also experience life threatening complications.

Thus, much information was collected from the patients' notes in order to enable an accurate and detailed description of the patient population. Similar types of information were collected from the notes of the SAH patients, although there are obvious inherent differences in this group, as will be seen in the following sections.



## 4.2 Subarachnoid Haemorrhage

Forty-four surviving patients, who were admitted consecutively to the RNU with a diagnosis of SAH, were entered into the study. The demographic and acute data collected for SAH patients were slightly different than for the TBI patients. In this case, GCS on admission and resultant WFNS grade was recorded in addition to side and site of aneurysm, and any operative procedure performed.

The demographic and acute medical information collected from patients' notes included:

- sex;
- age at the time of haemorrhage;
- Glasgow Coma Score (GCS) on admission and WFNS grade;
- site of aneurysm;
- side of aneurysm;
- operative treatment;
- complications.

### **SEX**

Of the 44 SAH patients entered into the study, 24 were female and 20 male. The ratio of females to males of 1.2:1 is roughly equivalent to that quoted in other studies of aneurysmal SAH (Gotoh et al. 1996).

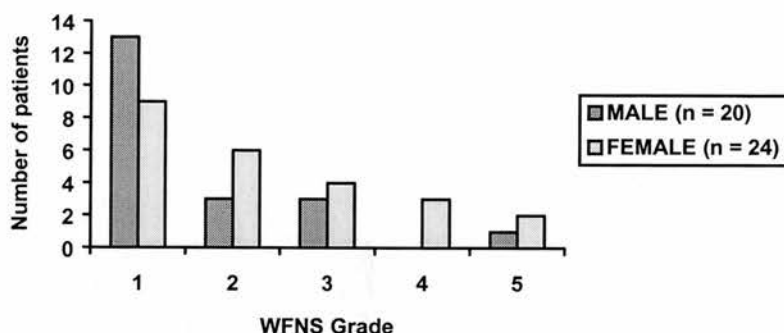
### **AGE**

The patients ranged in age from 22 to 77 years old. The group of 24 women had a mean age of 49.5 years (median 48.5; range 22 to 77), and the 20 men had a mean age of 50.0 years (median 49.0; range 24 to 70), revealing little difference between groups. Despite the wide age-range, 21 of the 44 patients (48%) were aged between 40 and 60 years, the age when rupture is reported to be most common (Lindsay et al. 1991).

### **ADMISSION GRADE**

The admission policy in Edinburgh is such that all patients with SAH are transferred to the RNU. Thus, by studying people who were admitted consecutively it was hoped to gain a representative sample of the population of survivors. As with the TBI study, all patients survived their initial admission and were discharged from the RNU.

**Figure 4.8**      **WFNS grade on admission and sex of patient**



Most patients were Grade I and II. This may be partly accounted for by the higher death rate in poor grade patients, and may also be a reflection of the admission policy to the RNU, so that many ‘good grade’ patients are transferred at an early stage enabling optimal care and management, and avoiding further neurological deterioration.

#### **SITE AND SIDE OF LESION**

All patients were diagnosed as having subarachnoid blood visible on their CT scans. The diagnoses were confirmed using angiography where possible and, in some cases, a lumbar puncture. Two patients were diagnosed as ‘unfit for angiography’, and a total of 9 patients (7 men and 2 women) had negative angiography despite the presence of subarachnoid blood on CT scan.

The angiograms were used to identify the site of the aneurysms, and details are given in the following table.

**Table 4.9**      **Site and side of aneurysm in SAH patients**

	Male		Female		Total
	Left	Right	Left	Right	Overall
ACoA	3	4	2	4	13
MCA	2	1	2	2	7
Post. Communicating	0	1	1	4	6
Internal Carotid	0	0	0	1	1
Carotid Bifurcation	0	0	2	1	3
Basilar	0	2	1	1	4
PICA	0	0	0	1	1

By collapsing this information into the classification of Lindsay et al. (1991) the proportions of patients with aneurysms at different sites are very similar to those reported there.

**Table 4.10      Proportion of patients with aneurysms at different sites**

	Lindsay et al.	Present Study
Middle Cerebral Artery	20 - 25%	20%
Posterior Circulation (Basilar artery; PICA)	10%	14%
ACA (ACoA + Pericallosal)	35 - 40%	37%
ICA (PCA; Carotid bifurcation)	30%	29%

It should be remembered that the data from the present study represent site of aneurysm in surviving patients only.

**NEUROSURGICAL INTERVENTION**

Thirty-five patients had aneurysms identified using angiography, of whom 33 underwent neurosurgical treatment to clip the ruptured aneurysms. Of these 33 patients, five had two aneurysms clipped. Although coiling of aneurysms is now being used within the RNU to treat aneurysm rupture, at the time of the study the usual method of treatment was clipping. One patient with a right sided posterior inferior cerebellar artery was managed conservatively, as was an elderly female patient with a Grade V SAH who was deemed unfit for surgery.

**COMPLICATIONS**

Only two patients were diagnosed as sustaining further injury from rebleeding of their ruptured aneurysm whilst in-patients during their initial admission to the RNU. This is a small proportion and is likely to be the result of the effectiveness of the surgical technique of clipping of the aneurysm, and the optimal management of patients through early referral and transfer to the RNU.

Nine patients (20%) were diagnosed as having delayed cerebral ischaemia (DCI), ranging from Day 2 to Day 13 after their initial bleed, using Transcranial Doppler (TCD). This is slightly higher than the estimates given by other workers. It may be the case that the use of TCD has improved the detection rate of DCI and that it may be more common than has been reported previously.

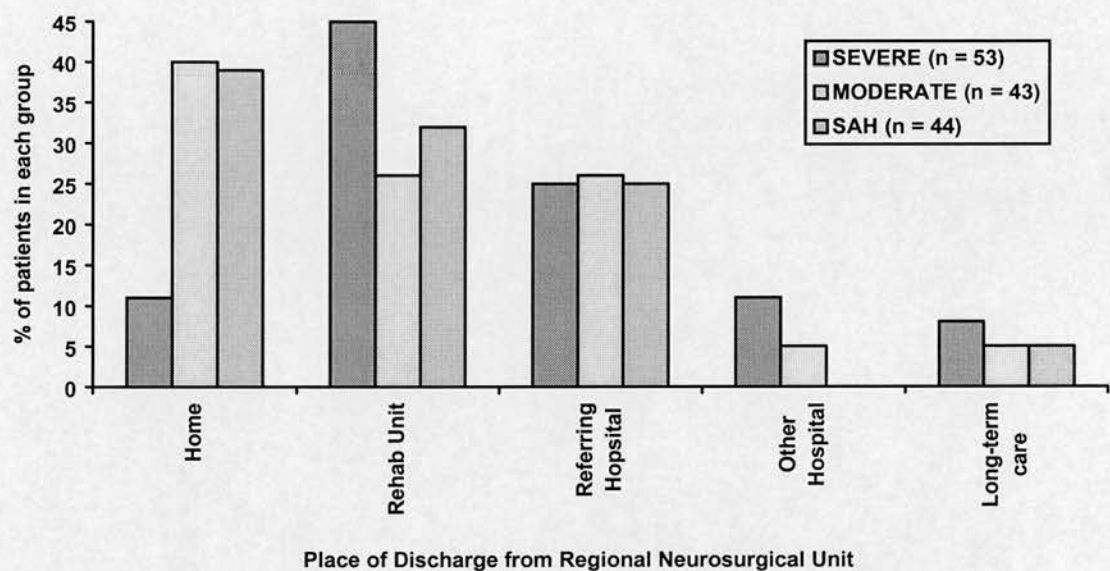
Hydrocephalus was identified in six patients, three of whom received neurosurgical intervention consisting of insertion of a shunt. Four patients developed post-traumatic epilepsy.

In terms of the frequency of extracranial complications, two patients suffered from hyponatraemia and one from pulmonary oedema.

### 4.3 Discharge Patterns of all Patients

The discharge pattern from the RNU was recorded for all patients, and the information is displayed in Figure 4.9 below.

**Figure 4.9      Place of discharge from the Regional Neurosurgical Unit in all patients**



A much higher proportion of the moderately injured patients were discharged home than in the severely injured group, and a higher proportion of severely injured patients were discharged directly to the acute rehabilitation facility. Some patients were referred to ‘other’ hospitals for continuing treatment of additional injuries sustained at the time of their TBI.

The proportion of SAH patients discharged home was comparable to the moderate TBI group, largely as a result of the number of patients with good grade SAH. Despite the fact that the SAH patients were not as severe as the TBI patients in terms of GCS on admission, a third were transferred directly to the acute rehabilitation unit. This emphasises the fact that SAH causes significant disability even in good grade patients. None of the SAH

patients were discharged to hospitals other than the rehabilitation unit or their referring hospital because of the lack of additional injuries in this group.

## 4.4 Comparison of TBI and SAH

### *Similarities*

The biggest degree of similarity between groups arises in the acute injury data collected. These show that patients with TBI or SAH experience injury to their brain causing lowering of consciousness which can, if severe, result in coma. Some patients in both the TBI and SAH groups sustained secondary injuries to their brain either from the formation of haematomas, or rebleeding of damaged vessels. In addition, both intra- and extracranial complications were noted in some patients in both groups. These included hypoxic injury, post-traumatic epilepsy, and cardiac and respiratory difficulties.

### *Differences*

The biggest differences between groups arose in the demographic information. As was expected, the TBI patients were younger than the SAH patients, although the age range of both groups was not dissimilar. The TBI group were predominantly male, whilst the SAH group had a higher ratio of females to males.



This chapter focuses on patients' outcome estimated using global measures. It includes descriptions of global outcome in the TBI patients, the SAH patients and a comparison of the similarities and differences between the two, before going on to describe the development and use of a new measure, the Edinburgh Extended Glasgow Outcome Scale (EEGOS).

## 5.1 Traumatic Brain Injury

The present study requested that patients were assessed on a range of cognitive tests and that a relative or friend completed an RQ concerning their recovery. The total information collected for each patient was used to aid assessment on the GOS. The specific criteria for application of the GOS categories were taken from the definitions provided by Jennett and Bond (1975). For some patients, a GOS was given on the basis of neuropsychological assessment or RQ, and in some patients on both. For a small proportion of patients, there was insufficient information available on which to base the GOS and in these cases the patient's GP was asked to assign a GOS based on their knowledge of the patient. Although this has been shown to be unreliable (Anderson et al. 1993) it was hoped that this method would be used infrequently, and approximately equally between patient groups. As in all studies of head injury some patients were lost to follow-up. Details of the methods used to obtain GOS scores are given in Table 5.1 below.

**Table 5.1** Basis of assignment of GOS scores (% of each group)

	6 months		12 months		24 months	
	severe	moderate	severe	moderate	severe	moderate
Died	4	7	4	7	8	7
Seen / RQ	87	81	87	81	72	74
GP Letter	6	7	8	7	13	14
Lost to follow-up	2	5	0	5	8	5

The category 'seen / RQ' denotes the number of patients who were seen in person or whose GOS was based on RQ information, and therefore reliable. Few GOS scores were based on the patient's GPs assessment and these were equally distributed between groups, thereby avoiding any bias. Of the 96 patients who were entered into the study, only one was lost to follow-up at all three assessment times. He was visiting Edinburgh at the time of his

accident, and was discharged from the RNU to a hospital near to his own home. He was not registered with a GP and no RQs were returned from his home address, either completed or indicating that he had moved.

**SEVERITY OF INJURY**

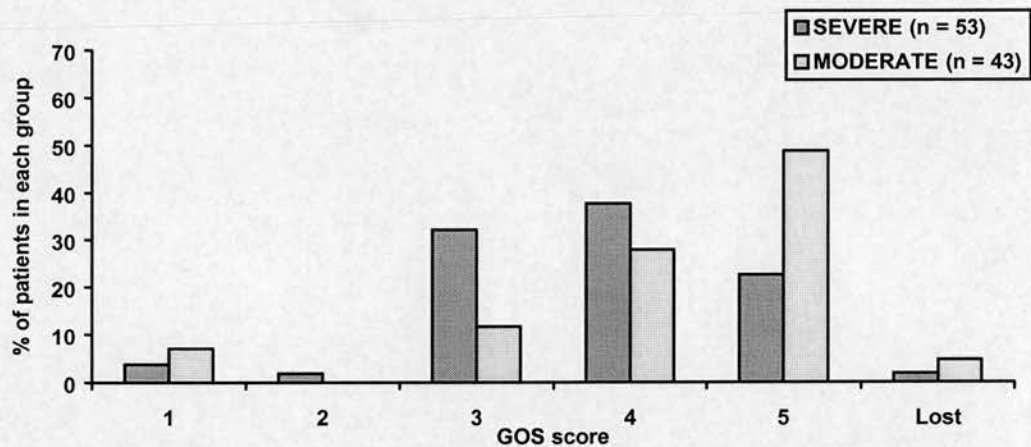
In order to compare the two measures of severity of injury employed in the study, the relationship between global outcome and both GCS and duration of PTA was investigated.

**Global Outcome and GCS on Admission**

*Six Month Outcome*

The following figure shows the relation between severity of injury based on GCS on admission and GOS at six months post injury.

**Figure 5.1      GOS outcome at six months post-injury**



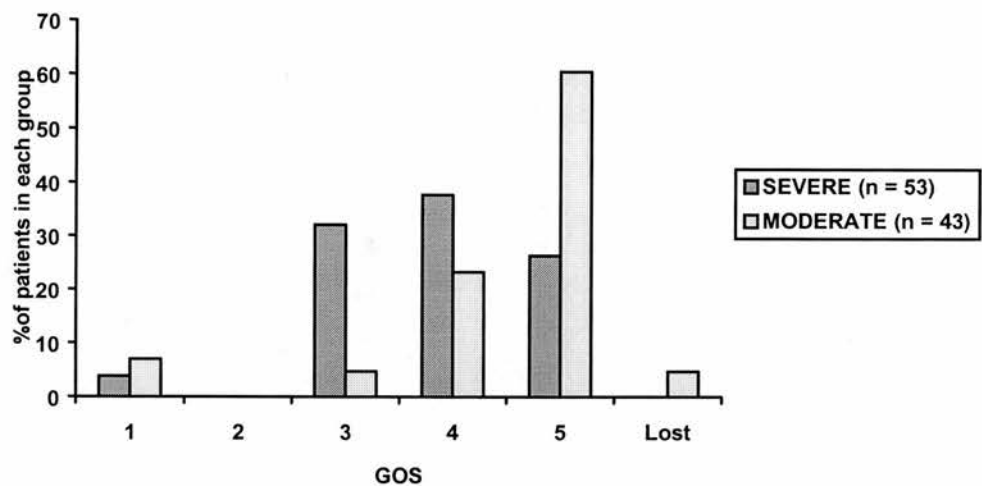
Although the study only included survivors of TBI, three moderate and two severely injured patients had died in the intervening period between discharge from the RNU and six month follow-up. In some cases the patient’s death was an indirect result of the head injury, and in others it was unrelated to the original injury.

The graph shows that those patients with a moderate TBI had a better outcome than those with severe injury, and a Chi-square test of the outcome of survivors revealed a significant difference between groups ( $\chi^2 = 9.77$ ;  $p = 0.008$ ).

*Twelve Month Outcome*

The following figure shows outcome as estimated using the GOS at 12 months post injury.

**Figure 5.2      GOS outcome at 12 months post injury**



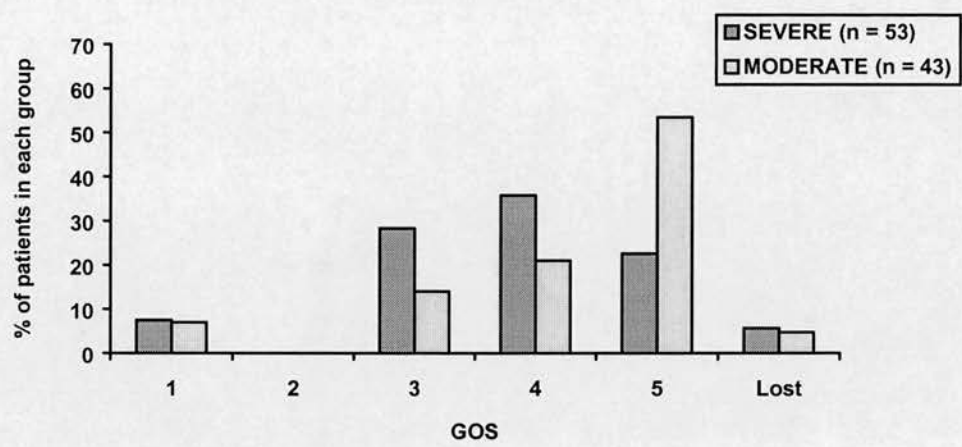
The outcome of the moderate TBI group is better than at six months, with fewer patients classified as severely disabled, suggesting continuing recovery over time. There appears to have been little change in the outcome of those with severe TBI. A Chi-square test showed a significant difference in outcome in conscious survivors between groups ( $\chi^2 = 17.24$ ;  $p < 0.001$ ), with moderate TBI patients having a better outcome than the severe TBI group.

*Twenty-four Month Outcome*

In the interval between one and two years post injury a further two severely injured patients died. One of these was a patient who had been in long term care since the time of her accident and her death was likely to be related to her condition. The other was a man who died as the result of an epileptic seizure following a period of binge drinking and failure to take his medication.

Figure 5.3 illustrates the difference in outcome between groups at 24 months post-injury.

Figure 5.3      GOS outcome at 24 months post injury



This graph shows a slight deterioration in outcome in the moderate group, with an increasing number classified as ‘severely disabled’. Again, there is little change in the group who sustained a severe TBI. Analysis of the data using a Chi-square test showed a significant difference in the outcome of surviving patients ( $\chi^2 = 10.21$ ;  $p = 0.006$ ) with moderately injured patients having better outcomes.

*Change over Time*

One of the biggest criticisms of the GOS is its insensitivity to change, so that any improvement or deterioration in a patient’s outcome is unlikely to be reflected by a change in GOS score. In order to look for change over time, a comparison was made between the proportion of conscious survivors in each category of the GOS at the three assessment times.

Table 5.2      Change in GOS score over time in severe and moderate TBI patients (in % of each group)

GOS	Severe			Moderate		
	3	4	5	3	4	5
6 months	34.7	40.8	24.5	13.2	31.6	55.3
12 months	33.3	39.2	27.5	5.3	26.3	68.4
Change	-1.4	-1.6	+3.0	-7.9	-5.3	+13.1
12 months	33.3	39.2	27.5	5.3	26.3	68.4
24 months	32.6	41.3	26.1	15.8	23.7	60.5
Change	-0.7	+2.1	-1.4	+10.5	-2.6	-7.9

For the severe TBI group the numbers of patients on which GOS scores were based were 49, 50, and 46 at six, 12 and 24 months respectively, and for the moderate group, GOS scores were based on 38 patients at all three intervals. The slight variation in proportions of the severe TBI group in each of the three outcome categories may partly be accounted for by the variation in patient numbers over the three assessment times. However, there appears to be no real change in the severe group when assessed using the GOS, which may be attributable to the lack of sensitivity of the scale. The only change over time appears to be an improvement in the outcome of the moderate TBI group between 6 and 12 months post-injury, followed by a deterioration between 12 and 24 months.

### Global Outcome and Duration of Post-traumatic Amnesia

The potential relevance of duration of PTA in terms of later outcome has been described by a number of authors. For example, Jennett et al. (1981) report that

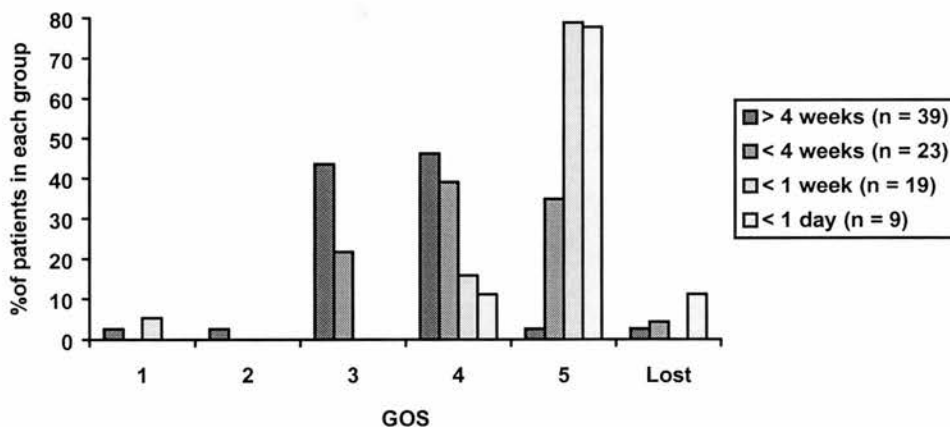
‘if a patient has emerged from PTA in less than four weeks he is almost certain to become independent, although he may be left moderately disabled’ (p290).

In order to compare outcome with duration of PTA the following series of graphs was plotted (Figures 5.4 - 5.6).

#### *Six Month Outcome*

At six months post-injury, surviving patients with a PTA of less than a week (including less than a day) were all independent, and most were classified as having made a good recovery. All patients who were classified as severely disabled had a duration of PTA of more than one week. Only one patient with a PTA of more than four weeks was classified as having made a good recovery, and one patient remained in a vegetative state.

**Figure 5.4** Six month outcome in relation to duration of PTA



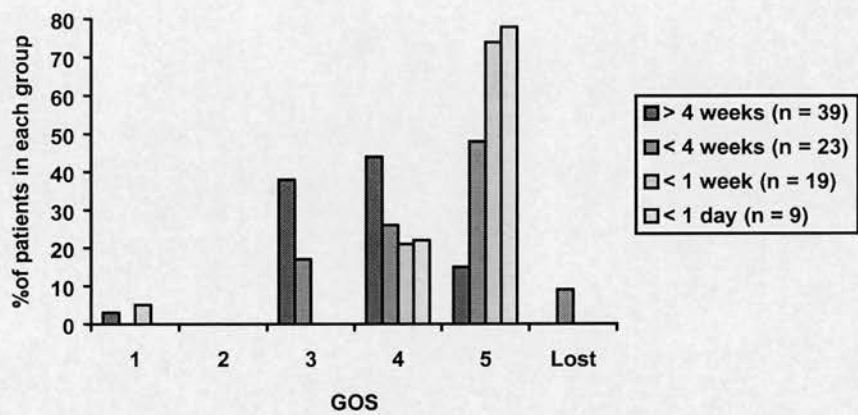


Analysis of duration of PTA and outcome in conscious survivors revealed a significant relationship ( $\chi^2 = 45.47$ ;  $p < 0.001$ ).

*Twelve Month Outcome*

At 12 months post injury, patients with a PTA of less than a week (including less than a day) remained independent, although the proportion classified as moderately disabled had increased slightly, largely due to the outcome of some patients who had been ‘lost’ at six months post-injury. The proportion of patients with a PTA of more than a week (including more than four weeks) classified as having made a good recovery had increased.

**Figure 5.5      12 month outcome in relation to duration of PTA**

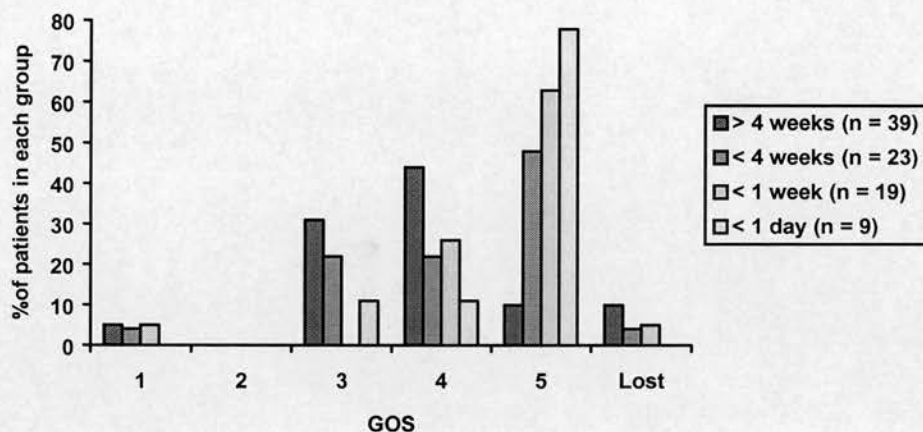


Again, analysis of the relationship between duration of PTA and outcome in surviving patients revealed a significant association ( $\chi^2 = 28.00$ ;  $p < 0.001$ ).

*Twenty-four Month Outcome*

At 24 months post-injury, patient outcome appears slightly worse with an increase in the proportion of patients classified as moderately disabled, and a fall in the proportion classified as making a good recovery. However, there is little change in the proportion who are dependent (i.e. severely disabled).

**Figure 5.6      24 month outcome in relation to duration of PTA**



Analysis revealed a significant relationship between duration of PTA and outcome in surviving patients ( $\chi^2 = 26.35$ ;  $p < 0.001$ ).

In agreement with the findings of Jennett et al. (1981) most patients with a PTA of less than four weeks recover to a level whereby they are independent, although a considerable number of these patients remain moderately disabled, even two years post-injury.

## OUTCOME AND ADDITIONAL INJURIES

### Injury Severity Score

Other workers have suggested that the patient's Injury Severity Score (ISS) is another good indicator of outcome following injury (Engberg, 1995). For this reason, the correlation between outcome and severity of injury as estimated using the ISS was also calculated. Spearman rank correlation coefficients gave correlations of  $r_s = -0.31$ ,  $p = 0.003$ ;  $r_s = -0.25$ ,  $p = 0.014$ ; and  $r_s = -0.31$ ,  $p = 0.003$  at six, 12 and 24 months respectively. This supports the results of Engberg, suggesting that outcome is related to the severity of multiple injuries, as indicated on the ISS, as well as to GCS and PTA.

However, it should be remembered that the ISS is calculated from an index of severity of the three most severe injuries to any body region, and so the ISS will be based, at least in part, on the severity of head injury. Thus the correlation between outcome and ISS may be attributable to the contribution of the brain injury in the calculation of the ISS. Some workers have attempted to overcome this by removing the head injury component from their calculation of the ISS (Dacey et al. 1991). The results of Dacey et al. revealed that neuropsychological outcome was only influenced by brain injury, and not by severity of

injury to other body systems. In contrast, psychosocial outcome was related to both brain and non-brain injuries. Unfortunately, because of the methods of data collection in the present study, it was not easy to calculate an ISS score minus the brain injury component, and no firm conclusions can be drawn from the results presented here.

### Complications

Investigation of complications in the two groups of patients revealed that they were more common and more severe in the severely injured TBI group than in that with moderate injury. It was also found that some patients in both groups suffered complications which were judged to be ‘life threatening’ by a member of the medical team. In order to see if the presence and severity of complications were related to outcome, non-parametric correlations were calculated between GOS outcome in survivors and number of complications, severity of worst complication, and sum of severities of complications. These correlations are shown in Table 5.3 below.

**Table 5.3      Spearman correlation coefficients between three measures of complications and outcome at six, 12 and 24 months post-injury (n = 96)**

	6 months	12 months	24 months
Number of complications	-0.48	-0.32	-0.34
	p <0.001	p = 0.002	p = 0.001
Worst severity of complications	-0.48	-0.41	-0.39
	p <0.001	p <0.001	p < 0.001
Sum severities of complications	-0.49	-0.35	-0.36
	p <0.001	p = 0.001	p = 0.001

The three measures of complications correlated highly with one another, as described in Chapter 4; Section 4.1. As can be seen from the table, all measures of complications proved to be significantly correlated with outcome as measured using the GOS. The strength of correlation decreased between 6 and 12 months, and thereafter remained relatively stable. The correlation with the severity of the most severe complication experienced by the patient persisted as the measure most strongly related to outcome. The presence and number of complications experienced by TBI patients appears to be linked to their outcome. However, the severity and presence of complications is in many cases related to the severity and nature of the patients’ original injuries. Nevertheless, some may be potentially avoidable and reduction of such complications might provide an opportunity to try and improve outcome in this patient group.

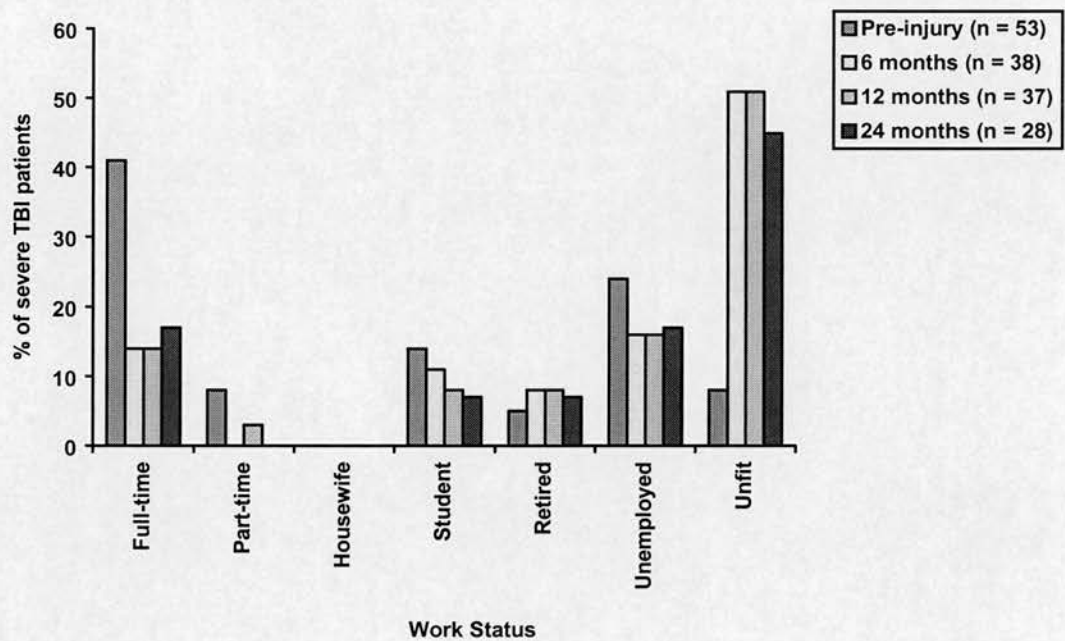
EMPLOYMENT

Details of return to work were collected, although the results must be interpreted in light of the many factors affecting employment in the general population at the present time. The results are shown for the severe and moderate TBI groups separately.

Severe TBI

At the time of injury, 41% of the severe TBI patients were in full-time employment, 24% were unemployed and 8% were unfit for work. At both six and 12 months post-injury, 14% were in full-time work, 16% were unemployed and 51% were unfit. At two years, there was a very small improvement in the work situation.

Figure 5.7      Return to work in the severe TBI group



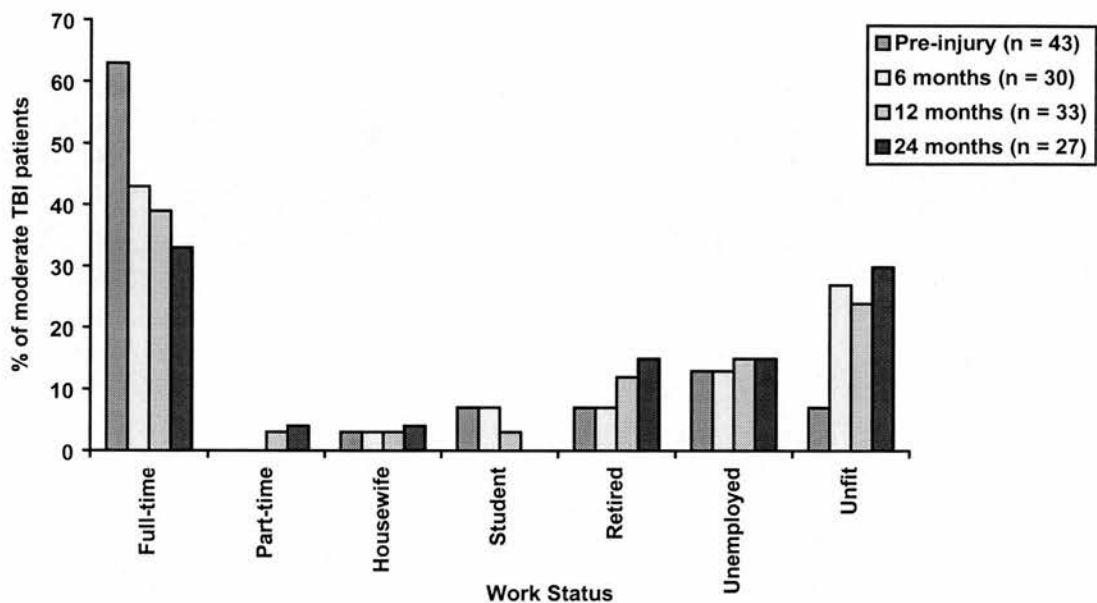
Moderate TBI

In the moderate TBI group, a similar if less extreme pattern of results was found (Figure 5.8 overleaf). At the time of injury, 63% of patients were in full-time work, 13% were unemployed and 7% were unfit. At six months post-injury, 43% were working full-time, 13% were unemployed, and 27% were unfit. However, over the two year period post-injury the proportion of patients in full-time work gradually decreased to 33%, accompanied by a rise in the proportion of patients who had retired. This may be accounted for by the fact that the moderate group were older than the severe TBI group, and some were offered early retirement. It is difficult to know if this is attributable to poor work performance or the



current economic climate. Nevertheless, 30% of the moderate group were unfit for work two years post-injury.

**Figure 5.8      Return to work in the moderate TBI group**



The many factors which influence return to work do not allow change in employment status to be attributed to the brain injury per se. However, comparison of the pattern of employment status pre-injury and at the three intervals post-injury illustrate the considerable reduction in the number of patients in full-time work, and the increase in those patients unfit for work and receiving benefit. The figures also show little change over time suggesting that the impact of the TBI on work status is long-lasting.

## 5.2 Subarachnoid Haemorrhage

The GOS has been used widely in studies of outcome following SAH and was used as a measure of global outcome with the present group. As with the TBI group, the GOS score was assessed on the basis of the total amount of information available for each patient from their cognitive assessment and/or RQ. In cases where there was no information available, a GOS was obtained from their GP. Details of the sources of information on which GOS scores were based is shown overleaf.



**Table 5.4** Source of information on which the GOS scores were based (in %)

	6 months	12 months	24 months
Died	0	2	5
Seen / RQ	95	86	75
GP Letter	5	11	18
Lost	0	0	2

Two patients died during the two year follow-up period, and five suffered further complications. One patient suffered meningitis between discharge and six month follow-up, and another four patients had suspected rebleeding; three between six and 12 months, and one between 12 and 24 months. Overall, there was a decrease in participation rate over time, although only one patient was lost to follow-up, at the 24 month assessment only.

### Global Outcome

The SAH group comprised mostly good grade patients, with only 6 patients classified as WFNS IV or V, analogous to GCS 3 to 12, although a majority of patients required neurosurgical intervention for their SAH. Therefore, it was not feasible to split the SAH group according to severity of injury.

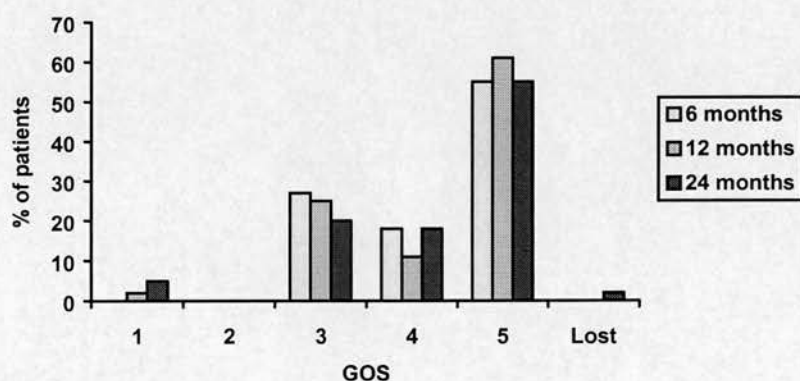
**Figure 5.9** Outcome of the SAH patients at six, 12 and 24 months post-haemorrhage (n = 44)

Figure 5.9 shows the outcome of the whole group at each of the three time intervals. Non-parametric correlations were carried out between WFNS Grade of SAH and outcome on the GOS. This revealed the following correlations at six, 12 and 24 months respectively:  $r_s = -0.56$ ,  $p < 0.001$ ;  $r_s = -0.48$ ,  $p = 0.001$ ; and  $r_s = -0.64$ ,  $p < 0.001$ .

### Change over Time

Comparison of global outcome at the three assessment times shows little change over time. Four of the patients who suffered complications months after their initial bleed were severely disabled at all time-points, and one made a good recovery. The two female patients who died several months after discharge were both severely disabled as a result of their initial haemorrhage, although one was living at home and the other was in long term care. The largest proportion of patients making a good recovery is recorded at 12 months, with a slight deterioration at two years.

### EMPLOYMENT

Details of return to work were collected, and are shown in the following graph (Figure 5.10).

**Figure 5.10      Return to work at six, 12 and 24 months post-haemorrhage**



The biggest difference can be seen in the proportion of patients in full-time employment, and those who are unfit for work. There is continuing improvement in return to work between six and 12 months, revealed by an increase in the proportion working full-time and a fall in the proportion in part-time employment. Despite the fact that a vast majority of these patients suffered good grade SAH, only about a third remain in full-time work as opposed to half of the group prior to their brain injury. In addition to this, 25 to 30% remain unable to work on the grounds of ill-health.

### 5.3 Comparison between TBI and SAH

#### *Similarities*

From a methodological perspective, both the TBI and SAH patient groups showed a decrease in the number of patients who were willing to participate over the duration of the study, with an increase in the number of GOS scores allocated by the patients' GPs at 24 months post-injury.

A comparison of the TBI and SAH groups in terms of outcome following brain injury shows a similar pattern: there appears to be a gradual improvement between six and 12 months followed by a slight deterioration in outcome between 12 and 24 months.

The reasons for this are unclear. It may be due to a deterioration in the patients' level of functioning or it may be the result of a lack of coping or increased stress in the patients' relatives or carers, who are more likely to report problems and difficulties later in the course of the patient's recovery. It is unlikely to be caused by a selective dropout of patients with a good recovery, because GOS outcome data were unavailable for only four patients (three TBI and one SAH) at 24 months, compared with one TBI patient at 12 months.

There is also a similarity in the pattern of work status between groups, with the proportion of both TBI and SAH groups in full-time work greatly reduced and a much higher proportion classified as unfit for work following their brain injury. The proportion of patients who remain unfit for work persists over the duration of the study in both TBI and SAH groups, suggesting that the impact of the brain injury on the patient's working life is likely to be long-lasting, if not permanent. The similarity in work status is greatest between the moderate TBI and SAH groups, partly as a result of the similarity in age between groups, and possibly because of a closer similarity in the severity of brain injury between groups in this present study.

#### *Differences*

The main difference between the TBI and SAH groups was in the work status pre-injury. None of the SAH patients was classified as 'unfit for work' prior to their injury, although 8% and 7% of the severe and moderate TBI groups respectively were classified as unfit. The most common reason given for TBI patients being unfit for work pre-injury was as a result of substance misuse.

Another difference which arose between groups was in the proportion of patients who were unemployed pre-injury. This was highest in the severe TBI group (24%), and lowest in the

SAH group (8%). This again emphasises the difference in the demographic details of the two patient populations, with the TBI patients drawn from the lower end of the socioeconomic scale, as described in Chapter 1 Section 1.1, and the SAH patients a more representative sample of the general population.

## 5.4 The development of a more sensitive global outcome scale

### *Rationale for a Modified GOS*

Looking at outcome of the overall groups as measured using the GOS, there was little apparent change over time. The GOS is a measure of global outcome with a very restricted number of categories. Its biggest limitation is that it is insensitive to change, so any attempt to modify it would be best directed at improving this insensitivity. In order to do this, the number of outcome categories must be increased, so that improvements which occur within the same outcome category on the GOS will cause a change in category on the new scale from one level to the next.

A number of attempts have been made to overcome this particular limitation of the GOS. The original GOS was modified (Jennett et al. 1981) by dividing each outcome category for conscious survivors into two, making an eight point scale. However, this led to a loss of reliability. A second study compared the inter-rater reliability of both the GOS and the same modified GOS and argued that:

‘it is the number of cases differently classified that matter, rather than a level of statistical association, and statistics were not, therefore, computed’ (Brooks et al. 1986; p550).

The level of agreement for the GOS was 70% and that for the modified GOS 46%, which the authors describe as ‘very high’ and ‘high’ respectively. This method of analysis takes no account of the size of disagreement between raters, which is of practical importance despite the authors’ assertions. The two raters in this study were the original authors of the GOS and it may be expected that the level of agreement between them should be better than between other less experienced users. The modified GOS was never really adopted although occasional reports of its use do appear in the literature (Engberg, 1995).

The Functional Scale of Recovery from Severe Head Trauma (Smith et al. 1979) was also developed from the original GOS but involved expansion into a 10 point scale. However, the authors provided no data concerning the applicability of the scale and it was not widely adopted.



A number of more detailed outcome measures have also been developed independently of the GOS. Perhaps the most successful of these is the Disability Rating Scale (DRS) (Rappaport et al. 1982) for severe head trauma. This is a 30 point scale comprising ratings on eight items which combine into four categories. It is more sensitive than the GOS in enabling the detection and identification of changes during recovery. The authors report that it is easily learned, quick to use, reliable and valid. Despite the success of the DRS it is not used to the same extent as the GOS, suggesting that there is still a need for a scale which is a compromise between the two. Other scales, such as the Level of Rehabilitation Scale (Carey and Posavac, 1982) and the Functional Life Scale (Sarno et al. 1973) have been criticised as excessively detailed, and cumbersome and time-consuming to use.

### **THE EDINBURGH EXTENDED GLASGOW OUTCOME SCALE (EEGOS)**

The original authors increased the number of GOS outcome categories available by dividing existing categories into two so that there could be high and low ends of severe disability, moderate disability and good recovery respectively. The other logical way of adapting the GOS is to keep the same outcome levels (severe disability, moderate disability and good recovery) but to specify a number of areas of function to which these refer.

Many authors refer to broad areas of function which may be affected by head injury. For instance, Najenson et al. (1980) suggest four categories involving cerebral function which may be affected: locomotion, communication, cognition and behaviour, whereas others categorise difficulties in terms of cognitive, physical and behavioural (Brooks, 1992) or cognitive, physical and personality change (Thomsen, 1984).

Three areas of functioning were chosen here to reflect the range of deficits following brain injury. They were (a) behavioural and/or emotional, (b) cognitive and (c) physical. This distinction was felt to be sufficient to enable the assessment of important functions affected by head injury, without being too detailed. Also, this particular categorisation has been used in the TBI literature for many years (Brooks and Aughton, 1979a; Medical Disability Society, 1988; Fearnside et al. 1993) and in discussion of outcome following SAH (Clinchot et al. 1994).

The EEGOS was developed by the present author from the original GOS, but is intended for use with conscious survivors of brain injury resulting from different causes. It uses the same scoring system as the GOS for level of recovery (3 = severe disability; 4 = moderate disability; 5 = good recovery) but requires application of these ratings to three different types of functioning:



- Behavioural and/or emotional
- Cognitive
- Physical

Each patient is assigned a score on each type of functioning, according to the criteria set out by the GOS:

**3** severe disability - dependent upon the help of another person for some activities, such as dressing or feeding, or using public transport.

**4** moderate disability - independent but disabled.

**5** good recovery - although some minor changes may be present.

In order to make the EEGOS reliable, strict criteria need to be set as to which specific functions fall into which category.

**Behavioural and/or Emotional:** This should cover social behaviour; emotional behaviour; family relationships; personality change; appropriate behaviour; disinhibition; irritability; temper; lack of insight, control of emotion, motivation, spontaneity; loss of emotion; mood swings; anxiety; depression; slowness.

**Cognitive:** This should cover the principal areas of cognitive functioning. Specifically, it should take into account functions such as:- orientation; memory; concentration; language (such as word finding abilities, comprehension, expression); visuo-spatial skills; planning; sequencing; judgement; abstract thinking; mental flexibility.

**Physical:** This should cover physical problems resulting from the head injury and not from orthopaedic injuries. Specific types of disability covered in this scale include:- fatigue; hemiplegia; ataxia; diplopia; dysarthria; dysphagia; disruption of vision, smell, or hearing; dizziness; poor balance; epilepsy.

The EEGOS retains the advantages of the original GOS in that there are explicit criteria for determining patients' level of disability, and a limited number of outcome categories. It attempts to overcome the insensitivity of the GOS by enabling discrimination of three levels of disability in three areas of function leading to 27 possible outcomes in conscious survivors.

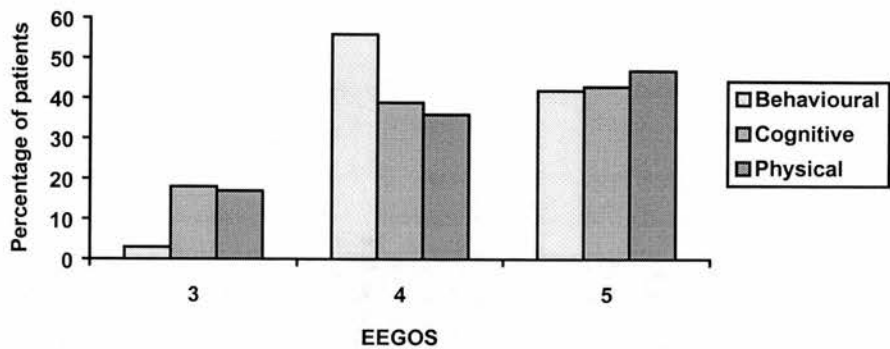
The reliability of the EEGOS was assessed in both 'live' and 'non-live' situations (see Appendix C). In the 'live' situation, patients were assessed independently by a doctor and a psychologist in two consecutive appointments on the same day, and an EEGOS given on the basis of the information. In the 'non-live' situation, results from cognitive assessment and the RQ were presented in a written form to a psychologist, a nurse and a physiotherapist, blind to the identity of the patient, and they were required to estimate outcome using the EEGOS on the basis of the written information. In both live and non-live situations, the EEGOS was found to give similar rates of agreement as the GOS. There was some variability between the subscales, with the behavioural subscale giving least reliable results and the physical subscale the highest level of agreement. This is likely to be attributable to the nature of the functions and their definitions. There is a much bigger degree of subjectivity in assessment of behaviour than in assessment of physical disability. It is possible for someone to exhibit extremely difficult or challenging behaviour and remain independent and such instances prove problematic for the EEGOS. However, the scale was shown to have reasonable psychometric properties.

The EEGOS was used in the present study to assess patients' outcome based on information from a cognitive assessment and/or RQ, as previously described for the GOS. The only difference between its completion here and the completion of the GOS is that GPs were not asked to estimate outcome using the EEGOS, as the reliability of its use in such a way has not been established. In order to investigate its utility, analysis of relationships with measures of severity of injury and analysis of change over time were attempted.

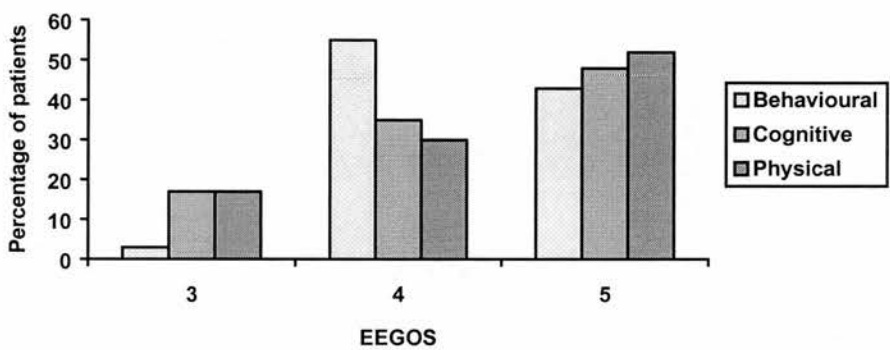
### **Traumatic Brain Injury**

Edinburgh Extended Glasgow Outcome Scale scores were ascribed to each patient at the same time as their GOS assessment. The following series of graphs shows the pattern of level of functioning in the whole TBI group over the three assessment periods (Figures 5.11 - 5.13).

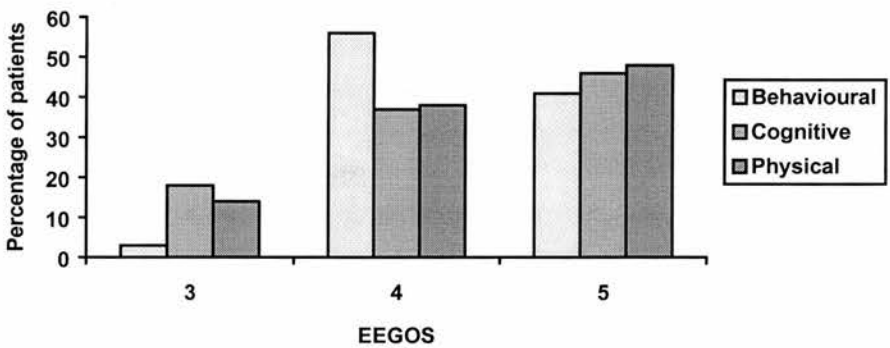
**Figure 5.11 EEGOS scores at six months post-injury (n = 72)**



**Figure 5.12 EEGOS scores at 12 months post-injury (n = 75)**



**Figure 5.13 EEGOS scores at 24 months post-injury (n = 63)**



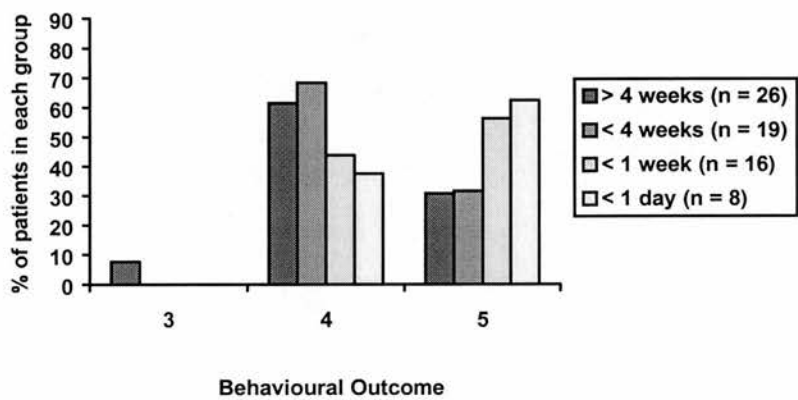
This illustrates that very few patients are ‘severely disabled’ because of behavioural and/or emotional change, but that in a majority of patients such problems are sufficient to be classified as causing moderate disability. The graphs also illustrate the continuing gradual improvement in physical functioning, with the proportion of patients severely disabled as a

result of physical problems decreasing over time. At each of the three assessment times roughly equivalent proportions of the patient group have achieved a good recovery in one or more of the three areas of function described.

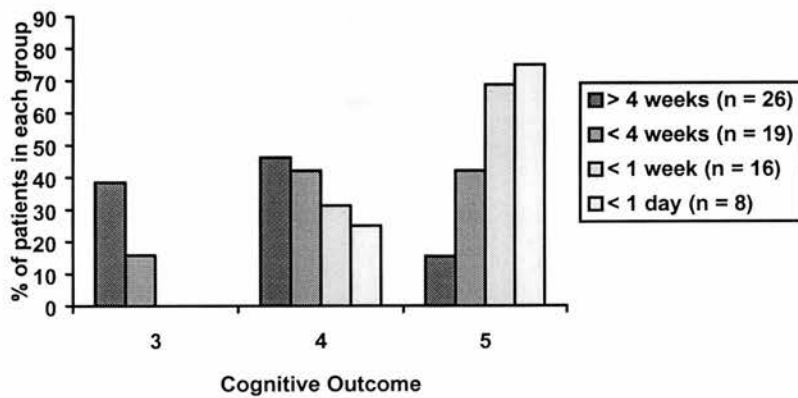
*EEGOS and Severity of Injury*

Analysis showed that there was a stronger correlation between duration of PTA and GOS outcome at six, 12 and 24 months ( $r_s = -0.697, p < 0.001$ ;  $r_s = -0.561, p < 0.001$ ;  $r_s = -0.528, p < 0.001$  respectively) than between patients' GCS on admission and GOS outcome ( $r_s = 0.466, p < 0.001$ ;  $r_s = 0.525, p < 0.001$ ;  $r_s = 0.459, p < 0.001$  respectively). For this reason, the following figures show the relationship between EEGOS scores at six months post-injury and duration of PTA.

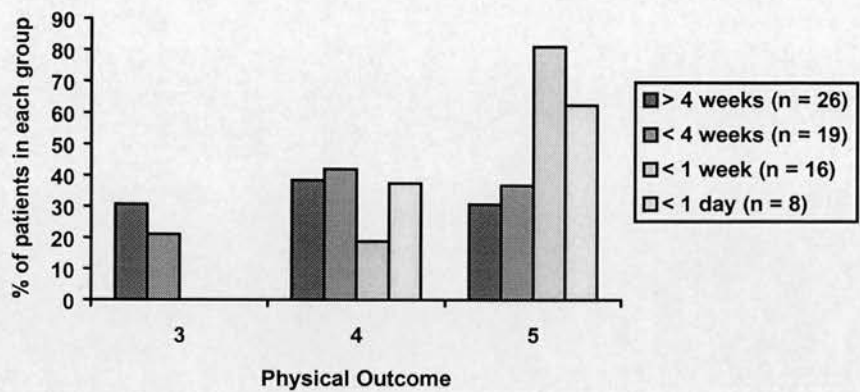
**Figure 5.14      Duration of PTA and behavioural outcome at six months post-injury**



**Figure 5.15      Duration of PTA and cognitive outcome at six months post-injury**



**Figure 5.16      Duration of PTA and physical outcome at six months post-injury**



At six months post-injury there is a consistent trend for those with longer duration of PTA to have poorer outcomes on all three subscales. The degree of correlation between duration of PTA and the EEGOS subscales was calculated at all three assessment times and is shown in Table 5.5 below:

**Table 5.5      Spearman correlation coefficients between EEGOS scores and duration of PTA at six, 12 and 24 months post-injury**

	6 months (n = 69)	12 months (n = 72)	24 months (n = 61)
Behaviour/Emotional	-0.26 p = 0.028	-0.28 p = 0.019	-0.13 p = 0.310
Cognitive	-0.53 p < 0.001	-0.52 p < 0.001	-0.47 p < 0.001
Physical	-0.40 p = 0.001	-0.44 p < 0.001	-0.42 p = 0.001

It can be seen that the duration of PTA has a relatively weak correlation with behavioural and emotional outcome, especially at 24 months post-injury, whilst duration of PTA is more strongly correlated with both the cognitive and physical outcomes of the patients. However, scores on the behavioural/emotional subscale are largely restricted to either 4 or 5 and this is likely to be the main contributory factor to the weak correlation. When correlations of EEGOS and severity using GCS on admission are made, the same pattern of results is found but the degree of correlation is smaller.



**Table 5.6** Spearman correlations between outcome on EEGOS subscales and severity measured by GCS on admission

	6 months (n = 72)	12 months (n = 75)	24 months (n = 63)
Behaviour/Emotional	0.21 p = 0.083	0.15 p = 0.194	0.09 p = 0.500
Cognitive	0.38 p = 0.001	0.43 p < 0.001	0.33 p = 0.008
Physical	0.29 p = 0.014	0.39 p = 0.001	0.27 p = 0.033

The results of this analysis support the use of duration of PTA as an indicator of outcome, as it correlates more strongly with scores on EEGOS subscales than does GCS on admission.

The strength of correlation between severity and outcome decreases over time, irrespective of the method of measuring severity of injury. This may be a reflection of the continuing recovery of patients with severe injury, whilst the recovery of those with moderate injury has slowed down. The results show that the severity of injury, however it is measured, has a long term effect on cognitive abilities, and to a slightly lesser extent, on physical functioning. There seems to be no relation between injury severity and long term behavioural and/or emotional outcome. Although the limitations of the subscale must be a contributory factor, there are a number of other possible explanations of this. Behavioural change may arise in response to frustration at some of the effects of the brain injury. Emotional response, such as an increase in anxiety or depression, may be associated with awareness of the nature and extent of impairment, or linked to real changes in situation such as reduction or loss of employment and change in family relationships. These may not necessarily be restricted to those patients with severe injuries. Some severe TBI patients may have little awareness of or insight into their difficulties, and so may not experience frustration. They may be unable to understand the financial implications of being unable to work and show little concern or anxiety about such matters, or about their future. It seems plausible that patients with moderate injury may have more awareness of the effects of their injury than those with severe TBI, which in turn may contribute to a larger degree of emotional or behavioural change. It may also be likely that those patients who display behavioural and/or emotional change are those who are moderately disabled (or ‘disabled but independent’) on the GOS. These are patients who are capable of living independently, but may be experiencing difficulties with employment or with their memory and/or

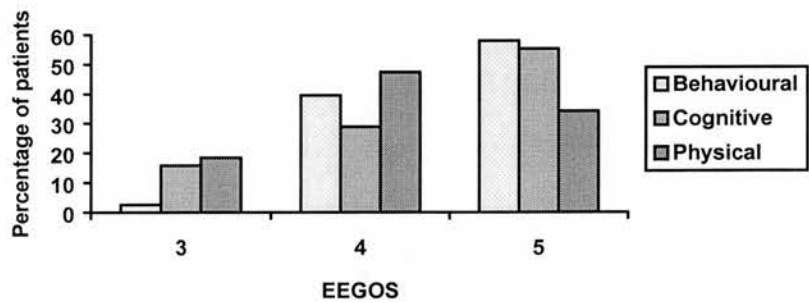
concentration, and may also be experiencing subjective symptoms such as headaches and tiredness. In many cases, these patients may have difficulty in obtaining additional financial support, such as Disability Living Allowance, because they appear physically fit and the extent of their ‘unseen’ disabilities is not fully investigated. This in turn contributes to financial worries, and added stress within the family. It is likely that these patients’ lives are quite markedly affected as a result of their TBI, and that they have sufficient insight and awareness to realise the long term problems and difficulties they are facing. This may lead to reactions such as frustration or anger, contributing to behavioural and emotional change, whilst not affecting their level of dependency.

**Subarachnoid Haemorrhage**

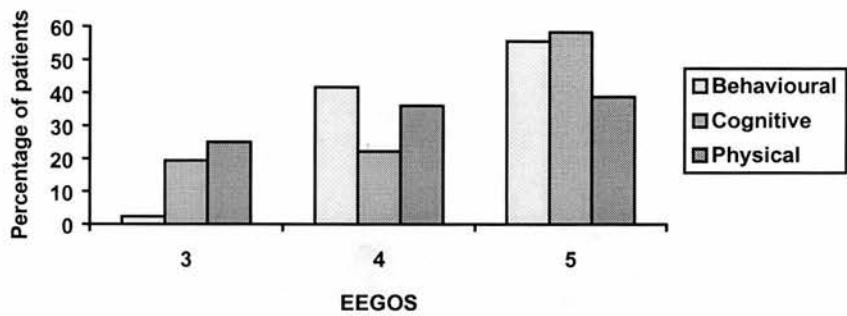
The EEGOS was derived to estimate outcome following acute brain injury of different aetiologies. The pilot studies included its use in a sample of SAH patients, and it was deemed suitable for use with the SAH group in the present study.

EEGOS scores were based on the maximum amount of information available for each patient, with the minimum requirement that there was either a completed RQ, or that the patient and relative were seen. Thus the number of patients on which EEGOS scores are available is less than those on whom GOS scores are given.

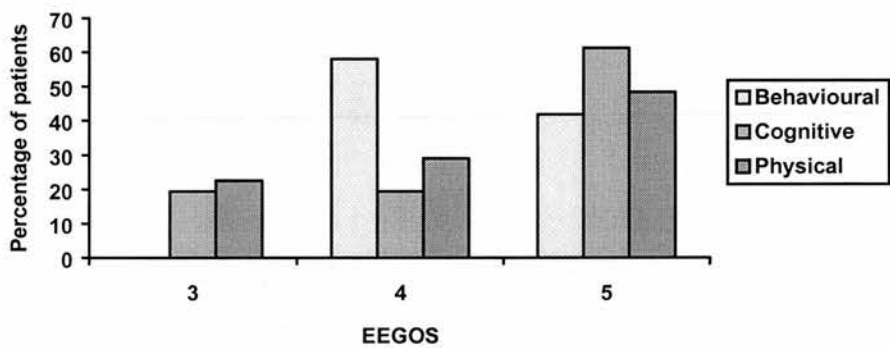
**Figure 5.17 EEGOS scores at six months post-haemorrhage (n = 38)**



**Figure 5.18 EEGOS scores at 12 months post-haemorrhage (n = 36)**



**Figure 5.19 EEGOS scores at 24 months post-haemorrhage (n = 31)**



The series of graphs shows that physical limitations are most likely to cause severe disability, but the proportion of patients with a good physical recovery continues to improve over time. Likewise, there is a small improvement in cognitive outcome over time. In contrast to this, behavioural and emotional change are increasingly reported over time, with 58% of patients classified as moderately disabled because of emotional or behavioural change at 24 months. The types of emotional and behavioural symptoms typically reported are passivity and apathy, mood swings and personality change.

Spearman’s correlations were carried out in order to investigate the relationship between severity of SAH and type of functioning affected.

**Table 5.7** Spearman correlations between outcome on EEGOS subscales and severity measured by WFNS grade

	6 months (n = 38)	12 months (n = 36)	24 months (n = 31)
Behaviour/Emotional	-0.17 p = 0.312	-0.03 p = 0.880	-0.28 p = 0.125
Cognitive	-0.37 p = 0.023	-0.38 p = 0.024	-0.60 p < 0.001
Physical	-0.30 p = 0.064	-0.50 p = 0.002	-0.54 p = 0.002

This shows that behavioural and emotional change do not seem to be related to severity of SAH, but this is again confounded by the limitations of the subscale. The higher correlation at 24 months between cognitive outcome and WFNS grade suggests that as the outcome of the overall group improves those with persisting cognitive impairments are those with poorer initial WFNS grade.

**Change over Time**

Although the EEGOS uses the same gross scoring system as the GOS, the fact that it entails scoring on three areas of functioning means that it may be sufficiently sensitive to denote improvement or deterioration on specific aspects of function. In order to look at change over time, scores on each subscale were compared at the three time intervals, according to severity of initial injury.

As the comparison was being made to look at the sensitivity of the scale to change over time, it was important that the scores were based on the same patients at each time interval. Therefore, only patients with EEGOS scores available at six, 12 and 24 months were used for this comparison. This gave 33 patients in the severe TBI group, 25 in the moderate group, and 30 in the SAH group. One of the difficulties with the EEGOS in this study is that scores could only be given if patients were seen and/or their RQ returned. Thus the number of patients on whom EEGOS scores are available is smaller than those for whom GOS scores are available, particularly at 24 month follow-up, and this decrease in attendance rate is reflected in the lower number of patients on whom EEGOS scores are available at all three assessment intervals.

### *Behavioural Subscale*

There is a difficulty with the behavioural subscale in that few patients are 'dependent' because of behavioural and/or emotional disorders, and so the use of the scale is largely restricted to categories 4 and 5. The pattern of results shows an improvement in the TBI patients between six and 12 months, followed by a deterioration in behavioural outcome over the following year. The SAH patients seem to show a consistent deterioration in behavioural function as illustrated by the increase in patients adjudged to be 'moderately disabled'.

**Table 5.8**      **Change in outcome on the behavioural subscale of the EEGOS ( in % of each group)**

	Score	6 months	12 months	Change	12 months	24 months	Change
sev	3	0	0	0	0	3.0	+3.0
sev	4	54.5	45.5	-9.0	45.5	57.6	+12.1
sev	5	45.5	54.5	+9.0	54.5	39.4	-15.1
mod	3	0	0	0	0	4.0	+4.0
mod	4	52.0	44.0	-8.0	44.0	48.0	+4.0
mod	5	48.0	56.0	+8.0	56.0	48.0	-8.0
SAH	3	0	0	0	0	0	0
SAH	4	36.7	43.3	+6.6	43.3	56.7	+13.4
SAH	5	63.3	56.7	-6.6	56.7	43.3	-13.4

### *Cognitive Subscale*

Cognitive outcome in the moderate TBI patients shows an improvement between six and 12 months, with little change over the following year. Those with severe TBI or SAH show little change throughout the duration of the study.



**Table 5.9**      **Change in outcome on the cognitive subscale of the EEGOS ( in % of each group)**

	Score	6 months	12 months	Change	12 months	24 months	Change
sev	3	24.2	24.2	0	24.2	24.2	0
sev	4	33.3	33.3	0	33.3	36.4	+3.1
sev	5	42.4	42.4	0	42.4	39.4	-3.0
mod	3	8.0	4.0	-4.0	4.0	8.0	+4.0
mod	4	36.0	28.0	-8.0	28.0	28.0	0
mod	5	56.0	68.0	+12.0	68.0	64.0	-4.0
SAH	3	16.7	20.0	+3.3	20.0	20.0	0
SAH	4	26.7	16.7	-10.0	16.7	16.7	0
SAH	5	56.7	63.3	+6.6	63.3	63.3	0

*Physical Subscale*

With physical functioning, the moderate TBI group show the biggest improvement between six and 12 months, followed by a small deterioration between 12 and 24 months. Both the severe TBI and SAH groups show fluctuations between all three assessments.

**Table 5.10**      **Change in outcome on the physical subscale of the EEGOS ( in % of each group)**

	Score	6 months	12 months	Change	12 months	24 months	Change
sev	3	24.2	21.2	-3.0	21.2	18.2	-3.0
sev	4	36.4	36.4	0	36.4	45.4	+9.0
sev	5	39.4	42.4	+3.0	42.4	36.4	-6.0
mod	3	8.0	4.0	-4.0	4.0	4.0	0
mod	4	36.0	24.0	-12.0	24.0	32.0	+8.0
mod	5	56.0	72.0	+18.0	72.0	64.0	-8.0
SAH	3	16.7	23.3	+6.6	23.3	20.0	-3.3
SAH	4	43.3	33.3	-10.0	33.3	30.0	-3.3
SAH	5	40.0	43.3	+3.3	43.3	50.0	+6.7

**Sensitivity of the Scale**

The comparison of change over time in the three patient groups was an attempt to see if the EEGOS was sensitive to change in specific types of function. The EEGOS revealed the biggest degrees of change in the moderate TBI group, with little consistent change in the severe TBI or SAH groups. The pattern of improvement and deterioration found in the

moderate group using the EEGOS was also seen when using the GOS, but the EEGOS enables this to be attributed to cognitive and physical function, rather than behaviour and emotional change.

For the SAH patients, the EEGOS reveals a gradual continuing improvement in cognitive and physical functioning over the three time periods, but it also shows a deterioration in behavioural and emotional function.

Comparing all three subscales, it can be seen that although few patients are ever categorised as severely disabled on the behavioural and emotional subscale, a large proportion of patients are classified as ‘moderately disabled’. This emphasises the high incidence of behavioural change in both the moderately and severely injured TBI patients, and the SAH group. This type of problem may be overlooked when considering outcome using the GOS, because it does not appear to contribute greatly to level of dependency.

The lack of any marked improvement on any of the scales would suggest that the EEGOS is restricted in its sensitivity, possibly as a result of using the gross outcome categories of the GOS. However, it may also be a reflection of little real change in the patient groups over time although the use of group data masks improvement and deterioration in individual patients. In order to examine this further, the proportion of patients in each group who improved or deteriorated by at least one category between six and 12 month assessments, and 12 and 24 month assessments, was calculated.

**Table 5.11      Proportion of patients (%) in each group who improve or deteriorate between assessments**

		Behavioural		Cognitive		Physical	
Assessment Intervals		6-12	12-24	6-12	12-24	6-12	12-24
Severe	Improve	9	3	6	12	12	6
	Deteriorate	0	18	6	12	6	9
Moderate	Improve	8	12	20	8	20	8
	Deteriorate	12	12	4	16	0	16
SAH	Improve	13	3	10	10	10	10
	Deteriorate	20	17	7	3	13	0

Thus, the EEGOS scores show improvement and deterioration in a considerable proportion of patients, although the extent of this change is hidden when looking at overall group

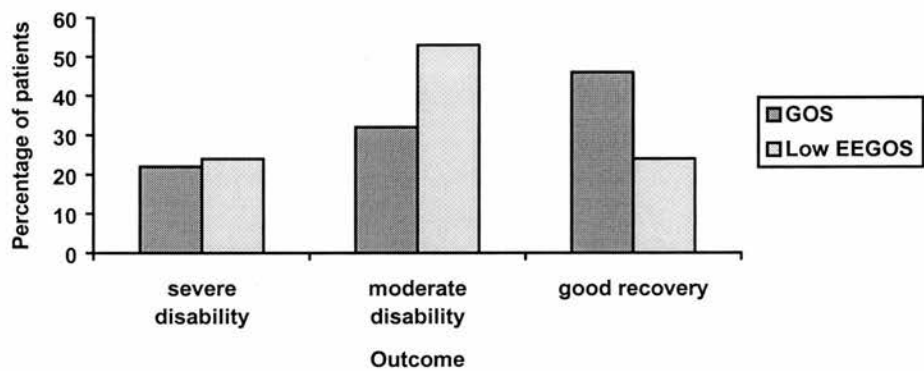
results. For example, between 6 and 12 month assessments, 13% of the SAH group show improved behaviour and/or emotion, whilst 20% show a deterioration.

The minimum proportion of patients who show change between assessments is 9% (behaviour in severe TBI patients between 6 and 12 month assessment) and the maximum proportion is 33% (behaviour in SAH patients between 6 and 12 month assessment), with subscales generally showing change (improvement or deterioration) in 20% to 25% of patients between assessments. This suggests that the EEGOS is sensitive to change over time, but because of the fluctuating nature of recovery in these patients, there is no overall marked change in the outcome of the groups as a whole. However, in tests of the reliability of the scale, the inter-rater agreements were 83%, 78% and 83% for the behavioural, cognitive and physical subscales respectively. Intra-rater reliability has not been investigated, although it would be hoped that levels of agreement would be higher than these. Nevertheless, some of the apparent improvement and deterioration in patients in the present study may be attributable to the degree of reliability of the scale.

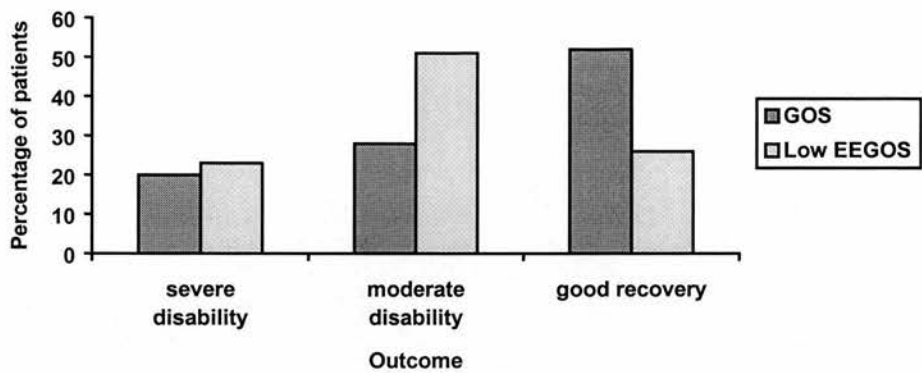
**EEGOS and GOS**

As both the EEGOS and GOS are measures of outcome based on the same scoring system, it seems logical that the worst score on the three EEGOS subscales *should* be equivalent to the GOS score. In order to investigate this relationship more fully, the following series of graphs was plotted, showing the comparison between lowest EEGOS score and GOS scores in all patients with GOS and EEGOS scores. The TBI and SAH patients were collapsed into one group giving data from 110, 111 and 94 patients at six, 12 and 24 months respectively.

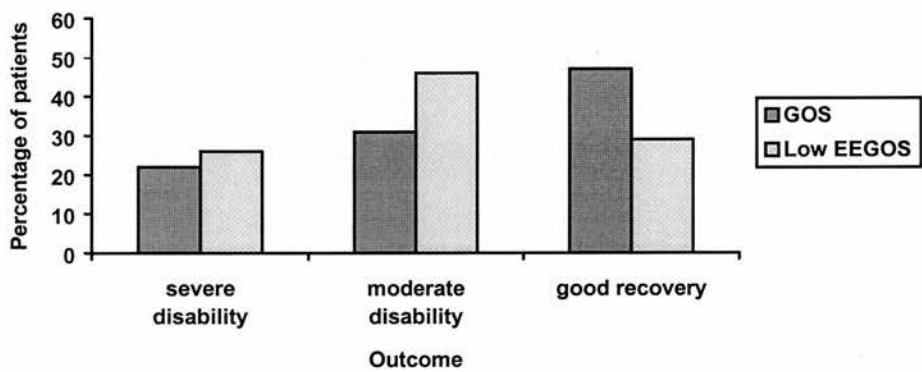
**Figure 5.20      Comparison between GOS and lowest EEGOS at six months (n = 110)**



**Figure 5.21      Comparison between GOS and lowest EEGOS at 12 months (n = 111)**



**Figure 5.22      Comparison between GOS and lowest EEGOS at 24 months (n = 94)**



Analysis of the relationship between GOS and lowest EEGOS gave Spearman rank correlations of  $r_s = 0.78$ ,  $p < 0.001$ ;  $r_s = 0.80$ ,  $p < 0.001$ ; and  $r_s = 0.85$ ,  $p < 0.001$  at six, 12 and 24 months respectively.

The graphs illustrate that whilst there is little difference between the number of patients who are classified as severely disabled using the GOS or lowest EEGOS, there is a much bigger difference between the categories of moderate disability and good recovery. Many patients who are classified as good recovery using the GOS have at least one EEGOS score of 4 (indicating moderate disability). This difference is likely to arise because of the ambiguity in the definition of good recovery in the original GOS:

“This implies the resumption of normal life even though there may be minor neurological and psychological deficits.” (Jennett and Bond, 1975; p483)

This has the effect that some patients classified as good recovery on the GOS have minor psychological or neurological deficits which makes them likely to be coded as ‘moderate disability’ on one of the EEGOS subscales.

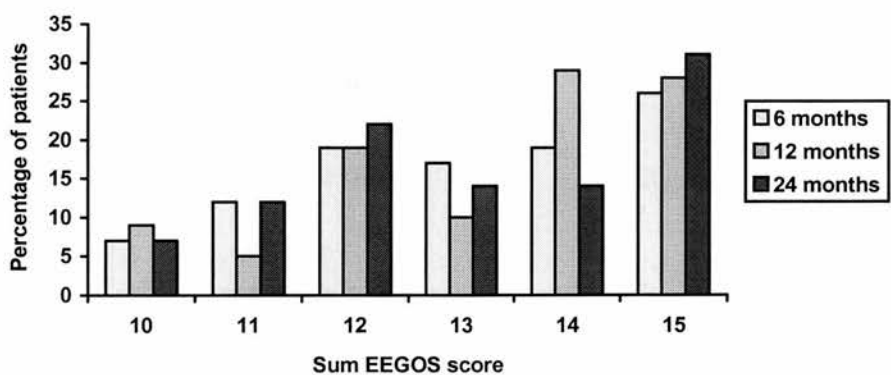
**Sum EEGOS**

Another possible option would be to sum up the three scores on the EEGOS, as is done with the GCS. Conscious survivors would have a total EEGOS score between 9, for someone severely disabled on all three subscales, and 15, for someone who has made a good recovery in all three areas of function. This gives a potential of seven outcome categories, which may make the scale more sensitive to change over time than the GOS.

However, one of the drawbacks of using this method is that two patients with intermediate scores may differ quite markedly. For example, someone who is dependent may have a score of 13 with EEGOS scores of 3, 5 and 5, whilst someone who is independent could have a lower sum score of 12 with EEGOS scores of 4, 4, 4. In order to look at the strength of the relationship between the GOS and sum EEGOS, Spearman rank correlations were carried out using data from the overall patient group, which gave the following values:  $r_s = 0.85, p < 0.001$ ;  $r_s = 0.83, p < 0.001$ ; and  $r_s = 0.90, p < 0.001$  at six, 12 and 24 months respectively.

In order to investigate the sensitivity of a sum EEGOS, the following graph of change over time was plotted from 58 TBI patients on whom an EEGOS score was available at each of the three assessment times.

**Figure 5.23      Sum EEGOS scores over the duration of the study (n = 58)**



The graph shows little consistent change over time in the EEGOS scores, although there appears to be some fluctuation over the time course of the study. The data presented show



that no patient had an EEGOS score of 9 in this subset of patients. Nevertheless, some patients did have a total score of 9, but did not have EEGOS scores at all three assessments and therefore their data were not included in this part of the analysis.

The usefulness of a sum score is by no means clear: it correlates closely with the GOS and because of the wider range of possible scores, it is more sensitive to change. Nevertheless, it effectively loses the information gained by scoring different areas of function separately.

### **Future development of the EEGOS**

The EEGOS is still in the early stages of its development. At present, the results are promising in that the early studies of the EEGOS reveal it to have a similar level of reliability as the GOS. It enables a more detailed description of the patients' outcome by permitting different scores according to different type of function. Thus the EEGOS enables the distinction to be made between patients who may be physically dependent but cognitively unimpaired, and those who may be physically well but cognitively dependent.

However, the EEGOS is somewhat restricted in its sensitivity to change, largely because it is based on the scoring system of the original GOS. Looking at the proportion of patients who either improve or deteriorate, the EEGOS reveals change in around 20 - 25% of patients on each subscale. The issue may be clarified by the use of a larger sample size to investigate patterns of recovery over time.

The EEGOS is also currently limited in that all trials of its use have been restricted to either face-to-face interview, or based on the considerable amount of information contained within the RQ.

Another difficulty which has arisen is the difficulty in defining the category of severe disability in the area of behavioural and/or emotional functioning. One obvious problem is that people often show behavioural change and yet remain independent. Thus the distribution of outcomes on the behavioural scale becomes largely restricted to the categories of moderate disability or good recovery. Disturbed or altered behaviour can be a cause of severe strain on the family, and can lead to problems with community re-integration and social interaction, and in such cases it may seem appropriate to classify it as causing severe disability. However, strict application of the definition 'needing the help of another person' may exclude them from this category, as their behaviour may not necessitate the help of another person, although it may warrant it. Although it may be possible to leave the estimation of severity of behavioural problems to the assessor's

discretion, the GOS has demonstrated that even with relatively strict definitions there is still room for disagreement between raters. Indeed, the behavioural scale showed the lowest levels of agreement between raters (Hellowell and Signorini, 1997b) suggesting the need for further clarification of the category definitions of this subscale.

## Chapter Six      Analysis of Cognitive Data

This chapter describes the results of analysis of data arising from formal cognitive testing and assessment of disturbed mood. It follows the format of the thesis so far considering firstly the TBI patients, then the SAH patients, followed by a brief comparison of the similarities and differences between the two. It begins with a brief overview of treatment of the data.

### **TREATMENT OF DATA**

In the present study, missing cognitive data arose for a variety of reasons: some patients were unable to complete assessment because of the extent of their impairment, some refused to participate in the study, some had an insufficient knowledge and use of English, and some had moved away from the area. In the literature, missing data arising from a patient being unable to complete the cognitive assessment have been treated in different ways by other research workers. Some have substituted missing data with scores *worse* than those of any tested patient on the basis that those patients who are unfit would be expected to perform poorly if they were capable of being assessed. This has the effect of assuming that all patients classified as 'unfit for assessment' are severely impaired on all aspects of function tested, which may lead to an overestimation of impairment. Other workers report substituting missing data using the mean substitution program in SPSS/PC+ (Ryan et al. 1992). This may lead to a misrepresentation of the extent of the patient's impairment, in that any averaged score would overestimate their ability, giving a conservative estimate of the extent of impairment. Other studies have excluded such severely disabled patients from their analysis (Fearnside et al. 1993). In the present study, data from patients who were unable to undertake assessment were coded as missing.

Comparisons of outcome on the GOS were made between those with and without cognitive test data at each time point, to see if those on whom cognitive test data were available comprised a representative sample of the study population.

### **Age Scaled Scores**

Performance on many neuropsychological tests is known to be affected by age. Broadly speaking, there is a deterioration in performance as people get older. In order to counteract the effects of age, raw test scores were converted to age-corrected scaled scores for all cognitive tests, on the basis of the best available normative data in test manuals or the literature (Wechsler, 1945; Benton et al. 1964; Wechsler, 1981; Kaplan et al. 1983; Enderby et al. 1987; Spreen and Strauss, 1991). Inevitably this process is approximate to a degree

that is dependent on the quality and extent of the available normative data. These age-scaled scores have a mean of 10 and a standard deviation of three in normative samples. This method of data transformation is commonly used, such as in the Wechsler Adult Intelligence Scales (Wechsler, 1981). Analysis of the raw scores was carried out and gave a very similar pattern of findings so only results of the analysis of age-scaled scores are reported here.

In addition to these analyses, all patients were given an overall test score, which consisted of the mean of his/her age-scaled scores.

**Estimates of Premorbid Intelligence**

Level of intelligence is also known to affect performance on some cognitive tests. Premorbid IQ was estimated using the NART, as described in Chapter 3; Section 3.2. As the patient groups did not comprise exactly the same patients at each of the three assessment times, comparisons were made between groups based on those patients who were assessed at each occasion. This revealed similar scores between groups at each time point, as described later, and any further computation was deemed unnecessary.

**6.1 Traumatic Brain Injury**

**Response Rates**

The number of patients who attended for assessment was recorded, and reasons for non-assessment noted.

**Table 6.1      Assessment rates, and reasons for non-assessment (% of each group)**

	6 months		12 months		24 months	
	Severe	Mod	Severe	Mod	Severe	Mod
Completed	49	56	43	58	40	40
Not appropriate/untestable	26	7	25	5	17	0
Refused to be assessed	8	12	9	14	4	21
Did not attend	2	9	8	12	15	23
Lived far away	6	0	6	0	6	5
Unable to trace	0	9	0	2	4	2
Other e.g. learning disabled	6	0	6	2	8	2
Patient had died	4	7	4	7	8	7

Patients who were untestable were seen at each of the three assessment times, and the severity of their impairment discussed with carers in order to ascertain the extent of their difficulties. A considerable proportion of severe TBI patients were untestable and although the number decreased over time, nine (18%) of the surviving 49 patients were unfit for formal assessment two years post-injury. Most were in long term care, although three were being cared for at home with support from social services.

At six months post-injury 14 male and 3 female patients (ratio of 4.67:1) were unfit for assessment. The mean age of the group was 43.6 years, and the median age 46, slightly older than that of the study population. Fourteen had sustained severe and three moderate TBI, defined using GCS on admission. Two patients had a PTA of between one and four weeks, and 15 patients had a PTA in excess of four weeks. Seven patients had sustained their injury in a fall, five were drivers involved in RTAs, three were pedestrians, one had jumped from a high wall and one had been assaulted. The mean ISS of the group was 25.2 (range 16 to 38), higher than that of the study population. The primary CT diagnoses were subdural haematoma in eight patients, diffuse injury and contusions in four patients each, and one case of an extradural haematoma. This illustrates that those patients who were unfit for assessment at six months were slightly older than the study population as a whole, and that they were more severely brain injured and had more severe multiple injuries than the study population. At 12 and 24 months, the patients who remained unfit for assessment were a subset of this original group.

Of those who refused to complete assessment, some were seen and problems they were experiencing were discussed, although they refused to undergo formal assessment.

Likewise, those coded as 'other' were seen and any difficulties discussed, although there was some reason, such as limited knowledge of English, which would have confounded their performance on any neuropsychological assessment. There was a between group difference in the reason for non-assessment, in that those with severe injury tended to be unfit for assessment whilst those with moderate injury were more likely to refuse or not attend their appointments ( $\chi^2 = 7.04$ ;  $p = 0.008$ ).

In order to establish whether the global outcome of those patients who completed neuropsychological assessment was any better or worse than those who did not, a Chi square test was carried out on GOS category, between assessed versus not assessed patients. This revealed that the patients with missing data had a significantly poorer outcome than those who completed the assessment, at six, 12 and 24 months post-injury ( $\chi^2 = 12.77$ ,



$p = 0.0017$ ;  $\chi^2 = 16.05$ ,  $p = 0.0003$ ;  $\chi^2 = 7.15$ ,  $p = 0.0280$  respectively).

## **COGNITIVE ASSESSMENT**

### **Premorbid Intelligence**

At six months post-injury, the NART scores of those patients who agreed to undertake assessment gave mean estimates of premorbid IQ of 99.7 for the severe TBI group, and 100.6 for the moderate group (s.d. 12.9 and 14.1 respectively). At 12 months, the mean estimated premorbid IQ scores were 100.7 for the severe group, and 101.1 for the moderate group (s.d. 12.8 and 13.3 respectively); and at 24 months, they were 102.5 for the severe group and 104.4 for the moderate group (s.d. 13.4 and 11.0 respectively).

Although mean estimated premorbid IQ was consistently higher in the moderate group throughout the duration of the study, the difference between groups was so negligible that no further computation was necessary to counteract any effects of intelligence.

### **Six Month Follow-Up**

Fifty patients (55%) underwent neuropsychological assessment; 26 severe and 24 moderate. This is a similar proportion to that reported in Kreutzer et al.'s (1993) study of outcome in a group of patients admitted consecutively with TBI.

At six months post-injury, a number of significant differences in performance between groups are revealed by unpaired t-tests. The overall test score of 9.4 for the group of moderately injured patients shows that they are performing a little below average (expected mean for the normal population = 10). The significant difference between groups is likely to be attributable to the extent of cognitive impairment in the severely injured patients.

The most significant difference between groups occurs on the Temporal Orientation Test (TOT), suggesting that those with severe injuries are significantly less well oriented than those with moderate injury. Other differences between groups, significant at the  $p < 0.01$  level, are found on the Boston Naming Test (BNT), the Digit Symbol subtest of the WAIS-R, and the delayed trial of the story recall task. In the case of the digit symbol and story recall tests, the differences are largely due to the poor performance of the severe TBI group, suggesting that they are slower and have a poorer verbal memory than the moderate TBI group, whose performance appears to be unimpaired relative to the normative data. In general, the scores of those with severe injury are somewhat lower than those with moderate injury, with the exceptions being the Digit Span and Modified Card Sorting Test (MCST), where both groups perform approximately equally well.

**Table 6.2**      **Age scaled scores on neuropsychological assessment at six months post injury (\* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ )**

Test Name	Severe (n=26)		Moderate (n=24)		p value	Sig. level
	Mean	s.d.	Mean	s.d.		
TOT	8.5	3.9	11.3	0.6	<.001	***
FAST	5.9	3.9	8.5	3.2	.021	*
Boston naming	2.4	2.1	4.8	3.5	.006	**
Story immediate	7.7	3.7	9.8	3.6	.058	
Story delayed	7.3	3.9	10.4	3.6	.010	**
Figure copy	8.3	2.9	10.1	1.7	.012	*
Figure recall	7.5	4.3	9.3	3.8	.129	
TMT A	6.4	2.6	7.4	2.3	.175	
TMT B	6.3	3.1	8.1	2.6	.059	
MCST cats	8.6	0.7	8.7	0.5	.740	
MCST errors	11.8	1.2	12.0	1.6	.647	
Digit span	10.2	3.1	10.6	3.1	.647	
Digit symbol	7.2	3.1	10.0	2.7	.005	**
Block design	9.3	3.6	11.4	3.0	.037	*
Overall test score	7.3	1.9	9.4	1.5	.005	**

Looking at the mean scores on individual tests, the scores of the severe TBI group tend to be well below the expected average norms, illustrating the presence of disturbances throughout many areas of cognitive function. However, both groups perform very poorly on the BNT. This would suggest that naming is a very common problem in patients following TBI, and is confirmed by patients' own reports of word-finding difficulties. Furthermore, poor mean scores on the Frenchay Aphasia Screening Test (FAST) would suggest the presence of a more global language disturbance. The Trail Making Test (TMT) also reveals poorer than average scores in both groups, but particularly in the severely injured. Neither group seems to perform particularly poorly on either the Digit Span or MCST, and results on the Block Design test show relatively good group mean scores, although there is a small but significant difference between groups. Data for the Paced Auditory Serial Addition Task (PASAT) are not presented, for reasons discussed later (see Chapter 8; Section 8.4).

**Twelve Month Follow-up**

Forty-eight patients (53%) underwent cognitive assessment at 12 months post-injury. They comprised 23 severe TBI and 25 moderate TBI patients.

At twelve months post-injury, the comparison of overall test scores between groups again shows a significant difference of  $p < 0.01$ .

**Table 6.3      Age scaled scores on neuropsychological assessment at 12 months post injury (\* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ )**

Test Name	Severe (n=23)		Moderate (n=25)		p value	Sig. level
	Mean	s.d.	Mean	s.d.		
TOT	9.6	3.7	11.2	1.2	.044	*
FAST	6.6	4.5	7.8	3.9	.396	
Boston naming	2.8	2.4	5.5	3.7	.007	**
Story immediate	5.0	2.5	7.3	2.9	.008	**
Story delayed	5.9	2.6	8.5	2.7	.004	**
Figure copy	9.6	2.7	10.0	1.8	.593	
Figure recall	7.7	4.6	11.3	3.3	.013	*
TMT A	6.9	3.3	8.4	2.6	.126	
TMT B	6.8	3.1	8.5	2.7	.091	
MCST cats	8.7	0.5	8.6	0.7	.553	
MCST errors	11.7	1.6	11.9	1.8	.659	
Digit span	9.2	4.2	11.0	3.3	.155	
Digit symbol	7.7	3.3	10.9	3.0	.004	**
Block design	10.0	3.9	12.8	2.7	.015	*
Overall test score	7.5	1.6	9.6	1.2	.003	**

As at six months post-injury, there are between-group differences significant at the  $p < 0.01$  level, on the BNT, the Digit Symbol and the delayed trial of the story recall test. Again, the scores are suggestive of a slower performance and poor verbal memory in those with severe TBI. On most tests the scores of the severe TBI group are generally somewhat lower than those with moderate injury, with the main exception being the MCST, where both groups perform equally well.

The group mean scores on individual tests show that the scores of the severe TBI group tend to be below the expected average norms. The pattern of performance is similar to that at six

months: both patient groups perform very poorly on the BNT, suggesting that word-finding difficulties are both common and quite marked. Likewise, both groups achieve relatively poor mean scores on the FAST. Again, the TMT reveals poorer than average scores in both groups, but particularly in the severely injured.

The most noticeable difference between six and 12 month assessments is in performance on the story recall test of verbal memory. It appears that both groups show a deterioration in verbal memory, in contrast to general improvement on tests of other cognitive function. However, it should be remembered that 'parallel forms' of both the verbal and visual memory tests were used at the 12 month assessment period. Other workers (Iverson, 1986; Henry et al. 1990) have suggested a difference of approximately 3 points between the two parallel forms of the verbal memory test used and this is likely to account for the apparent deterioration in verbal memory<sup>2</sup>. The visual memory test shows a bigger between group difference on the recall trial at 12 months than at six months, largely due to an improvement in score by the moderate TBI group. However, these scores should be interpreted with caution, because the use of parallel forms may be contributing to the difference in scores.

As at six months, both groups perform relatively well on both the Digit Span and MCST, and results on the Block Design test show average or above average group mean scores, although again there is a small but significant difference between groups.

### **Twenty-four Month Follow-up**

At 24 months post-injury, only 38 patients (43%) underwent cognitive assessment. They comprised 21 severe TBI and 17 moderate TBI patients. The decrease in patient numbers is almost entirely due to a drop in attendance by those with moderate TBI. This may be because they felt they had made a sufficiently good recovery or did not like to take time off work unnecessarily.

A comparison of overall test scores between groups showed a significant difference. Full details of the test scores are given in Table 6.4 overleaf. At 24 months post-injury the differences between groups are much smaller. As pointed out, the number of patients attending for assessment had dropped, particularly those with moderate injury. It might be expected that the moderate TBI patients who had attended were those with the most impairment. If this is the case then the performance of those who attended is likely to be

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<sup>2</sup> It should be noted that the difference of 3 points is in the raw test score and so will translate to a smaller difference in the age scaled score.

biased toward the poor end of performance of the whole population. This may contribute to the diminution of the difference in performance between groups.

**Table 6.4** Age scaled scores on neuropsychological assessment at 24 months post injury (\* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ )

Test Name	Severe (n=21)		Moderate (n=17)		p value	Sig. level
	Mean	s.d.	Mean	s.d.		
TOT	9.4	3.8	9.4	4.1	.964	
FAST	7.0	4.1	9.5	2.8	.037	*
Boston naming	4.2	3.3	7.1	2.8	.010	**
Story immediate	9.0	3.5	11.2	4.0	.092	
Story delayed	8.9	3.2	11.6	3.3	.020	*
Figure copy	8.4	3.3	9.4	2.8	.307	
Figure recall	7.7	5.1	10.7	3.3	.047	*
TMT A	8.2	2.9	9.7	3.4	.223	
TMT B	7.3	3.0	9.2	2.7	.098	
MCST cats	8.6	0.8	8.8	0.0	.305	
MCST errors	11.5	2.9	12.6	0.5	.170	
Digit span	9.7	3.6	11.6	2.4	.114	
Digit symbol	9.7	3.2	12.0	3.3	.099	
Block design	10.6	3.0	13.8	2.7	.006	**
Overall test score	8.2	1.8	9.7	1.6	.122	

However, looking at the mean scores for the moderate TBI group, most are at or above the average norms. This might suggest little or no impairment in performance relative to the general population, but at this stage considerable practice effects may have accumulated. These practice effects might be greater in people with less impairment assuming that they are not performing at a ceiling level.

The biggest difference between groups at 24 months is in performance on the Block Design test. However, both groups are performing at an above-average level, and this difference is attributable to the superior performance of the moderate TBI group rather than an impaired performance of the severe group. The BNT continues to show a between-groups difference significant at  $p = 0.010$ . Although a number of other tests continue to reveal between-group differences, the significance level of these differences has fallen to the  $p < 0.05$  level partly



as a result of the reduction in the number of cases. Again, there is no significant between-group difference on Digit Span or the MCST.

The group mean scores on individual tests show a continuing difficulty on the BNT in both patient groups, suggesting the persistence of word-finding difficulties. Patients in the severe TBI group appear to have continuing difficulty with the FAST, TMT and recall of visual material.

### Number of Patients

The comparison and analysis of the mean scores of both patient groups on the range of tests included within the battery revealed few difficulties in the moderately injured group. The number of patients whose scores fell below one standard deviation of the mean was also counted, a method which has been used by other research workers to classify impaired performance (Kreutzer et al. 1993).

**Table 6.5      Percentage of TBI patients with age-scaled scores more than 1 s.d. below the mean<sup>3</sup>**

Test Name	6 months		12 months		24 months	
	severe	mod	severe	mod	severe	mod
	(n=26)	(n=24)	(n=23)	(n=25)	(n=21)	(n=17)
TOT	37	0	21	8	15	9
FAST	62	29	50	35	40	18
Boston naming	95	71	94	58	72	38
Story immediate	53	29	82	50	29	20
Story delayed	58	21	67	31	29	7
Figure copy	17	4	11	8	22	12
Figure recall	52	26	44	12	56	18
TMT A	60	29	53	17	25	19
TMT B	67	33	53	22	58	13
MCST cats	5	5	5	4	6	0
MCST errors	0	5	0	4	6	0
Digit span	15	16	28	6	13	8
Digit symbol	47	4	47	5	20	7
Block design	32	0	26	0	7	0

<sup>3</sup> These numbers represent percentages of patients who completed the tests. There will be slight variation in the number of patients who completed each test at each assessment session, for reasons such as refusal or hemiplegia.

Approximately 16% of normal people should score below this arbitrary cut-off at their first assessment. The table shows some percentages lower than this, reflecting the limitations of the available normative data for some tests, whilst for others, it remains rather surprising. There appear to be particular problems with the normative data for the Block Design and MCST tests, and these will be discussed later (see Chapter 8; Section 8.4).

Again, this reveals a larger proportion of patients in the severe TBI group with suggestion of cognitive impairment. However, the advantage of using this method is that it reveals a proportion of patients in the moderate group who are experiencing difficulty on several of the tasks, and yet whose poor performance is likely to be masked in any analysis of mean group data.

The general trend which becomes apparent from this table is that the proportion of patients showing poor performance on these tests decreases over time, suggesting continuing recovery of cognitive function. Although the number of patients attending for assessment decreased, most noticeably between 12 and 24 months, it was thought to be most likely that those who were returning for assessment were those with the biggest degree of impairment. There were two reasons for this. First, a number of patients telephoned to say that they did not wish to attend at 24 months because they felt fine, or they did not want to take time off work unnecessarily. Second, there was a much smaller difference in GOS outcome between those who were and were not assessed at 24 months, suggesting that the proportion of patients with good outcome and who were not assessed had increased markedly since the 12 month assessment. If this is the case, then any estimate of recovery over time, based on neuropsychological assessment, will be a conservative one.

The data reveal large proportions of patients in both groups who are impaired on the BNT, and this would appear to improve little over time, suggesting that word-finding problems are common and persistent.

The data also reveal an increase in the proportion of patients with apparently poorer verbal memory scores at 12 months than either 6 or 24, again emphasising that this is likely to be attributable to the use of a parallel version of the test at that time period. Conversely, the proportion of patients with impaired performance on the complex figure test of visual memory was considerably less at 12 months than either 6 or 24, suggesting that this may be easier than its parallel form. The complex figure tests have been reported to be of comparable complexity by some authors, but not the majority (Lezak, 1995).

Use of this method of looking at the data also reveals that very few patients had poor performance on the MCST at any of the three time intervals post-injury. The MCST has been widely used with TBI patients, and impaired performances have been found especially in patients with frontal lobe lesions. Even allowing for the limitations in the computation of age-scaled scores from limited available normative data, the results of the current study suggest that the MCST may not be as sensitive to brain lesions as previously thought. Examination of raw scores produced a similar conclusion. Another complicating factor is that many patients had performed the MCST during the early stages of their recovery, and remembered the three sorting strategies in the MCST. In such case, performances may be artificially high because of practice effects.

**MOOD DISORDERS**

The Hospital Anxiety and Depression Scale (HAD) (Zigmond and Snaith, 1983) was used at all three assessment sessions to identify the presence of a mood disorder. Using cut-off levels suggested by the authors, the results show no significant difference between groups in the prevalence of anxiety or depression at any of the three assessments, as illustrated below.

**Table 6.6      Prevalence of anxiety in patients over time (shown in %)**

	Severe Head Injury				Moderate Head Injury			
	n	none	borderline	anxious	n	none	borderline	anxious
6 months	26	72	8	20	24	65	9	26
12 months	23	68	8	24	25	62	11	27
24 months	21	47	42	11	17	70	11	19

The prevalence of anxiety disorders in primary care practice has been estimated at 7% (Goldberg, 1995). Table 6.6 shows that anxiety is relatively common following TBI, apparently irrespective of the severity of injury. The incidence of clinical anxiety at 2 years post injury is less than at 6 and 12 months suggesting that there may be improvement over time. However, a considerable proportion of the severely injured patients are at a ‘borderline’ level, suggesting an increase in level of anxiety compared with before injury, although not sufficient to warrant the label of ‘clinical anxiety’. It should also be remembered that fewer patients completed assessment at 24 months than at the earlier two time intervals, which may cloud the issue. Also, people who sustain TBI are not a representative sample of the population.

**Table 6.7      Prevalence of depression in patients over time (shown in %)**

	Severe Head Injury				Moderate Head Injury			
	n	none	borderline	depressed	n	none	borderline	depressed
6 months	26	76	16	8	24	78	18	4
12 months	23	76	12	12	25	85	4	11
24 months	21	79	11	11	17	88	6	6

Table 6.7 shows that the prevalence of depression is lower than that of anxiety, and remains relatively constant over time. The prevalence of depression in primary care practice has been estimated at 12% (Goldberg, 1995), so the levels reported in the current TBI population would appear in keeping with those in the general population.

The data were analysed to look for an association between mood disorder and measures of severity of injury or cognitive impairment. There was no significant relationship between severity of injury measured either by GCS on admission or duration of PTA. Other workers have reported a significant relationship between emotional disorder and degree of cognitive impairment (Arcia and Gualtieri, 1993). However, there was no significant correlation between overall test score and level of anxiety or depression on any assessment occasion. In addition to this, some of the more severely impaired patients who completed a HAD lacked insight into the extent of their disabilities. Thus they were unaware of the full effects of their deficits, potentially influencing the amount of anxiety and/or depression they reported. At interview, patients with less cognitive impairment and more insight into the extent of their difficulties tended to express worries and anxiety about their condition, or their employment or financial situation.

It is important to remember that not all patients completed a HAD. Those who did not comprised people who were so severely disabled that they were unfit for formal assessment as well as those who refused to take part in the study. Thus the sample of patients on whom an assessment of mood disorder was made is biased. Nevertheless, the prevalence of anxiety reported here is considerably higher than that reported in the general population.

## 6.2 Subarachnoid Haemorrhage

The analysis of cognitive data for SAH patients followed the same data transformation as that of the TBI patients. Age-scaled scores were computed for all patients on all tests.



### Response Rates

Reasons for non-assessment were noted and are shown below.

**Table 6.8      Assessment rates and reasons for non-assessment (in %)**

	6 months	12 months	24 months
Completed	64	50	43
Not appropriate/untestable	9	16	14
Refused to be assessed	7	9	14
Did not attend	16	18	16
Moved away	5	5	7
Unable to trace	0	0	2
Patient had died	0	2	5

Approximately 10% of patients were unfit for assessment, rising to 14% during the time-course of the study. Five patients suffered further neurological complications following discharge from the RNU: four were severely disabled as a result of their initial SAH, and following their complications, one died and the remaining three became unfit for formal assessment. The fifth patient did not want to participate in the study but was classified as having made a good recovery by her GP.

As with the TBI patient groups, a Chi-square test was carried out to see if there was any difference in global outcome as measured using the GOS between those patients who undertook cognitive assessment and those who didn't. The analysis revealed that the patients with missing data had a poorer outcome than those who completed the assessment, at six, 12 and 24 months post-injury ( $\chi^2 = 7.56$   $p = 0.023$ ;  $\chi^2 = 5.53$ ,  $p = 0.063$ ;  $\chi^2 = 6.42$ ,  $p = 0.040$  respectively).

### COGNITIVE ASSESSMENT

#### Premorbid Intelligence

The NART was used to estimate premorbid IQ, and in order to compare this with the TBI groups, mean NART scores were computed for the SAH group at each of the three assessment times. This revealed mean scores of 105.5, 104.6 and 104.2 at six, 12 and 24 months (s.d. 13.7, 14.4 and 15.1 respectively), comparable to the TBI groups.



### Six, Twelve and Twenty-four Month Follow-up

Data from all three assessments are presented together. Twenty-eight patients (64%) were assessed at six months, with 22 (50%) and 19 (45%) assessed at 12 and 24 months respectively. These assessment rates, corrected for death, are similar to those of the TBI groups.

**Table 6.9**      **Age scaled scores on neuropsychological assessment**

	6 month (n = 28)		12 month (n = 26)		24 month (n = 19)	
	Mean	s.d.	Mean	s.d.	Mean	s.d.
TOT	10.9	1.5	10.9	1.6	10.1	2.6
FAST	7.8	3.0	8.9	3.6	9.7	2.5
Story immediate	9.7	3.4	7.8	2.4	11.5	2.7
Story delayed	10.3	3.7	9.5	2.2	12.3	2.5
Figure copy	9.0	3.1	10.8	1.3	9.5	2.5
Figure recall	9.7	3.5	13.0	2.8	11.3	3.2
TMT A	9.0	3.1	10.1	3.2	10.5	3.3
TMT B	9.4	2.7	10.2	2.8	9.8	3.0
MCST cats	8.7	0.4	8.9	0.3	8.8	0.2
MCST errors	11.9	1.6	12.3	0.9	12.3	1.1
Overall Score	10.0	1.3	10.1	1.4	10.1	1.6

Although the mean group scores do not appear to show any marked impairment, the same pattern can be seen in the SAH patients as was found with the TBI group, although there are difficulties in drawing direct comparisons between the groups because the extent of the initial brain injury in the two groups was not comparable. The results also show an increase in score over the assessment period, suggesting that recovery continues for many months post-haemorrhage.

### Number of Patients

The number of patients whose scores were poorer than one standard deviation below the mean was counted. This revealed some patients who were performing poorly on several of the tests, which is masked by the use of group mean scores. The pattern of deficits is similar to that found in the TBI group, although by 24 months, performance is at least as good as that which would be expected in the general population, illustrating the limitations of the norms and transformations used.

**Table 6.10 Percentage of SAH patients with age-scaled scores more than 1 s.d. below the mean**

	6 month	12 month	24 month
TOT	7	9	11
FAST	31	26	11
Story immediate	19	35	0
Story delayed	19	9	0
Figure copy	15	0	21
Figure recall	26	0	11
TMT A	26	14	11
TMT B	30	14	11
MCST cats	4	0	0
MCST errors	4	0	0

The data show that a number of patients were experiencing language disturbances as revealed on the FAST, and similarly, a number of patients performed poorly on the TMT. However, there is continuing improvement over time to such an extent that by 24 months there would appear to be little impairment on formal assessment in this patient group. Nevertheless, it should also be remembered that the proportion of the original patient group who were not able to undertake formal assessment rose from 10 to 14% during the time-course of the study. Thus it appears that in the SAH patient group some patients show a good recovery of function, whilst others remain severely disabled, with few patients in between.

As with the TBI group, the parallel versions of the verbal and visual memory tests would not seem to be of equivalent difficulty. The version of the story recall test used at 12 months appears considerably more difficult than that used at 6 and 24 months, whilst the complex figure test used at 12 months would seem to be easier than the version used at 6 and 24 months.

## MOOD DISORDERS

The HAD was used with the SAH group to detect the presence of a mood disturbance. Details of the prevalence of anxiety and depression are similar to those reported in primary care practice (7% and 12% respectively) (Goldberg, 1995).

**Table 6.11      Prevalence of anxiety and depression in SAH patients over time (shown in %)**

	Anxiety Subscore			Depression Subscore		
	none	borderline	anxious	none	borderline	depressed
6 months (n = 28)	81	11	8	92	0	8
12 months (n = 26)	70	17	13	83	9	9
24 months (n = 19)	79	21	0	89	5	5

Storey (1967) reported psychological symptoms in 55% of a large sample of SAH patients, assessed between six months and six years later. He concluded that some of the symptoms were caused by anxiety or depression rather than being organic in nature. However, in the present study the prevalence of anxiety and depression was approximately equivalent to that found in the normal population, and would seem unlikely to be a major contributory factor here.

### 6.3 Comparison between TBI and SAH

#### *Similarities*

There are similarities between patient groups in the reasons given for non-assessment, with similar attendance rates at each of the three assessment times, and a comparable degree of drop-out over time.

The assessment of patients following TBI or SAH showed that both patient groups were experiencing disturbed language abilities, and although the mean scores of the SAH group were not particularly depressed, they showed the same pattern of performance as those of the TBI groups. The similarity in the pattern of impairment is especially evident when looking at the proportion of patients with scores of 1 standard deviation or more below the mean, with language difficulties, and memory and concentration problems most noticeable. Both the TBI and SAH patients show improved scores over time, suggesting continuing recovery for at least two years post-injury.

#### *Differences*

Analysis of the cognitive assessment of the TBI and SAH groups shows that patients with TBI had a much greater cognitive impairment than the SAH patients. However, this is likely to be partly attributable to the difference in severity of injury between groups, and the high rate of complications in the SAH patients who were severely disabled, rendering them unfit for formal assessment. However, there may be a difference in the underlying pattern

of cognitive impairment, with the SAH patients either having a good or poor cognitive outcome, whilst many of the TBI patients recover to an intermediate level.

Again, when comparing the prevalence of mood disorders in the two groups, fewer of the SAH patients are identified as suffering from either anxiety or depression. Both TBI groups reported symptoms of anxiety more frequently and more severely than symptoms of depression, the opposite pattern to that found in primary care practice (Goldberg, 1995).

# Chapter Seven      Reported Information

This chapter will describe results from measures of reported behaviour; either reported by a relative in the form of the RQ, or patients' self-report using the HISC.

## INFORMATION FROM A RELATIVE

Neuropsychological test performances do not correlate perfectly with neuropsychological difficulties in everyday life. For this reason, the information given in the RQ proved helpful in ascertaining change in the patient's level of functioning resulting from their injury.

Another benefit of using the RQ is that some patients with past histories of alcohol abuse show impaired performance on some cognitive tests as a result of brain atrophy from excessive alcohol consumption (Solomon and Malloy, 1992; Mearns and Lees-Haley, 1993). In such instances it is difficult to determine whether these impairments are a result of their TBI or their alcohol misuse. The use of the RQ was intended to aid estimation of change resulting from the brain injury alone.

## 7.1 Traumatic Brain Injury

### RELATIVE'S QUESTIONNAIRE DATA

The contents of the RQ can be classified into the following eight categories<sup>4</sup> (Gray et al. 1994):

language	3 questions
memory	6 questions
physical symptoms	10 questions
emotional symptoms	7 questions
disturbed behaviour	6 questions
social behaviour	3 questions
subjective symptoms	7 questions
dependency	7 questions

A raw score was used for each category. Brooks et al. (1986a) converted the raw scores to scores out of 10 for each category, but this can lead to excessive apparent weight being attached to items in categories with few questions. For example, the language category consists of three questions and the physical symptoms category consists of 10. If a relative

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<sup>4</sup> Although the RQ comprises 62 questions, only 49 are used in the scoring system. The remaining questions refer to work status, type of employment, cause of injury or compensation claims.



reports one symptom in each category, this will give scores of 3.3 and 1.0 respectively when scaled up to a score out of 10.

The questionnaire asks relatives to report whether there has been any change in the patient's functioning by indicating either **no change**, **rather worse since injury**, or **much worse since injury**. In scoring the questionnaire, the latter two classifications were collapsed, giving the distinction of either no change or some change. This was done because of the likelihood of a high degree of variation between relatives' opinions of what constitutes 'rather worse' and 'much worse', when the real interest was in whether or not there had been any change.

**Return Rates**

Questionnaire data are not available for all patients. Return rates of the RQs at 6 and 12 months were good but by 24 months the return rate had dropped. Reasons for non-return of the RQ were recorded. In some cases, where the patient remained very severely disabled, the questionnaire was considered inappropriate by the present author, and a small number of patients reported that there was no-one close to them who could complete the questionnaire. Full details are given in Table 7.1 below.

**Table 7.1      Return rates of RQs and reasons for missing information (% in each group)**

	6 months		12 months		24 months	
	Severe	Mod	Severe	Mod	Severe	Mod
Completed	70	70	70	77	53	63
Not appropriate	9	0	9	0	9	0
Refused to take part	2	0	2	0	0	0
Not returned	6	12	9	14	25	19
No-one to complete	4	2	6	0	2	7
Unable to trace	0	7	0	0	4	2
Other e.g. every box ticked	6	2	0	2	0	2
Patient had died	4	7	4	7	8	7

It was not appropriate to compare GOS scores between patients who returned their RQ and those who did not, because of the difference in methods of scoring the GOS. The GOS scores for patients who had completed neuropsychological assessment or who had returned an RQ were based on detailed information and believed to be reliable. The GOS scores allocated by the patients' GPs have been shown to be unreliable (Anderson et al. 1993), and

would confound the comparison between groups, as all of these patients would be restricted to the non-RQ group.

**Six Month Follow-up**

At six months post injury 37 questionnaires were returned by relatives of patients with severe injury, and 30 questionnaires were returned by relatives of those with moderate injury. The return rate, corrected for death, is 74%.

The number of reported symptoms in both groups was compared on each of the eight categories, using Mann-Whitney U tests (Table 7.2). The results indicate that there are no significant differences on any of the categories of functioning, although there is a trend in the expected direction (i.e. patients with more severe initial injuries showing more alteration in functioning) with the exception of emotional symptoms which were equally reported between groups.

Table 7.2		Mean number of reported symptoms per category of function at six months post injury				
Function (Maximum Value)		Mean No. of Symptoms (s.d.)				Sig. Level (p value)
		Severe (n=37)		Moderate (n=30)		
Language	(3)	1.22	(1.27)	0.63	(0.84)	0.087
Memory	(6)	2.35	(2.20)	1.31	(1.56)	0.072
Physical	(10)	3.72	(2.58)	2.67	(2.29)	0.109
Emotional	(7)	3.36	(2.85)	3.37	(2.62)	0.956
Disturbed Behaviour	(6)	1.94	(1.88)	1.66	(1.68)	0.648
Social Behaviour	(3)	1.40	(1.22)	1.07	(1.11)	0.295
Subjective	(7)	3.94	(2.57)	3.56	(2.49)	0.509
Dependency	(7)	2.97	(2.30)	1.93	(2.02)	0.073
Total	(49)	19.4	(14.9)	15.8	(11.3)	0.650

The ten most commonly reported individual problems in each group were identified and are shown in Table 7.3 overleaf.

**Table 7.3      Most commonly reported individual symptoms at six months (% of patients affected)**

Severe TBI (n = 37)	Moderate TBI (n = 30)
Balance 73%	Tiredness 67%
Employment affected 73%	Tension 63%
Memory 68%	Impatience 57%
Leisure affected 65%	Memory 57%
Tiredness 62%	Passivity 53%
Slowness 62%	Irritability 50%
Passivity 59%	Temper 50%
Tension 59%	Concentration 50%
Personality change 54%	Personality change 50%
Supervision outdoors 54%	Leisure affected 47%

It should be remembered that these symptoms relate to individual questions on the RQ, and that although a high proportion of the moderately injured patients are reporting some symptoms, the total number of symptoms reported is smaller in the moderate group than in the severe.

### **Twelve Month Follow-up**

At the 12 month follow-up, 37 questionnaires were returned by patients with severe injury and 33 by patients with moderate injury. The return rate, corrected for death, is 77%. This is slightly better than at six months, due to the fact that three patients who had moved away had been re-traced at 12 months, and returned completed RQs.

The mean number of reported symptoms is shown in Table 7.4 overleaf. At 12 months post injury, Mann-Whitney U tests revealed only one significant difference between groups, which is the patients' reported level of dependency ( $p < 0.05$ ), with relatives of severe TBI patients reporting a higher degree of dependency than relatives of patients with moderate TBI.

**Table 7.4      Mean number of reported symptoms per category of function at 12 months post injury**

Function (Maximum Value)	Mean No. of Symptoms (s.d.)		Sig. Level p value
	Severe (n=37)	Moderate (n=33)	
Language (3)	0.94 (1.11)	0.88 (1.21)	0.747
Memory (6)	1.82 (1.79)	1.47 (1.72)	0.465
Physical (10)	3.39 (3.04)	2.33 (2.09)	0.223
Emotional (7)	3.63 (2.66)	3.85 (2.49)	0.806
Disturbed Behaviour (6)	2.53 (2.06)	2.06 (1.78)	0.361
Social Behaviour (3)	1.44 (1.11)	1.19 (1.15)	0.343
Subjective (7)	3.81 (2.18)	3.57 (2.33)	0.727
Dependency (7)	2.55 (1.99)	1.53 (1.85)	0.014
Total (49)	15.6 (11.4)	14.8 (10.2)	0.814

In a number of other categories, there is a tendency for relatives of patients with severe injury to report more changes than those with moderate injury, but the differences between groups are not large. Emotional changes are reported slightly more frequently in the group of patients with moderate head injury. The 10 most commonly reported symptoms for each group are shown below.

**Table 7.5      Most commonly reported individual symptoms at 12 months (% of patients affected)**

Severe TBI (n = 37)	Moderate TBI (n = 33)
Personality change (76%)	Tiredness (70%)
Memory (68%)	Impatience (70%)
Passivity (65%)	Tension (67%)
Employment affected (65%)	Irritability (64%)
Slowness (62%)	Personality change (64%)
Balance (59%)	Memory (64%)
Tiredness (59%)	Depression (61%)
Tension (59%)	Concentration (58%)
Impatience (59%)	Mood swing (58%)
Concentration (57%)	Less sociable (55%)

Again, some symptoms are very commonly reported. Relatives of three-quarters of the severe TBI group and almost two-thirds of the moderate group report personality change. Change in memory and concentration are reported in over half of the patients in each group, illustrating the importance of assessment of cognitive function. The moderate group report a preponderance of changes in social and disturbed behaviour.

#### Twenty-four Month Follow-up

At 24 months post injury, 28 RQs were returned from the severe TBI group, and 27 from the moderate TBI group, giving a return rate of 62% corrected for death. This fall in the return rate was a result of a rise in the number of patients not returning the questionnaires.

Comparison of the mean number of symptoms reported by each group is shown below.

**Table 7.6 Mean number of reported symptoms per category of function at 24 months post injury**

Function (Maximum Value)	Mean No. of Symptoms (s.d.)		Sig. Level p value
	Severe (n=28)	Moderate (n=27)	
Language (3)	1.04 (1.37)	0.70 (0.87)	0.559
Memory (6)	1.57 (2.04)	1.46 (1.84)	0.941
Physical (10)	3.67 (2.97)	2.88 (2.59)	0.290
Emotional (7)	2.91 (2.66)	3.56 (2.67)	0.417
Disturbed Behaviour (6)	2.00 (1.95)	2.23 (1.53)	0.614
Social Behaviour (3)	1.10 (1.19)	1.15 (1.10)	0.784
Subjective (7)	3.58 (2.21)	3.58 (2.37)	0.976
Dependency (7)	2.65 (2.53)	1.77 (2.23)	0.351
Total Symptoms (49)	16.1 (13.6)	16.4 (12.7)	0.762

Mann-Whitney U tests show no difference between groups on any of the 8 categories of functioning as reported by relatives. There is a trend for physical symptoms and dependency to be more commonly reported in severely injured patients, but emotional and behavioural problems are more commonly reported following moderate injury.

Again, problems with memory and concentration are reported in over half of the patients in each group (Table 7.7). The predominance of emotional and behavioural change in the moderate group is also upheld.



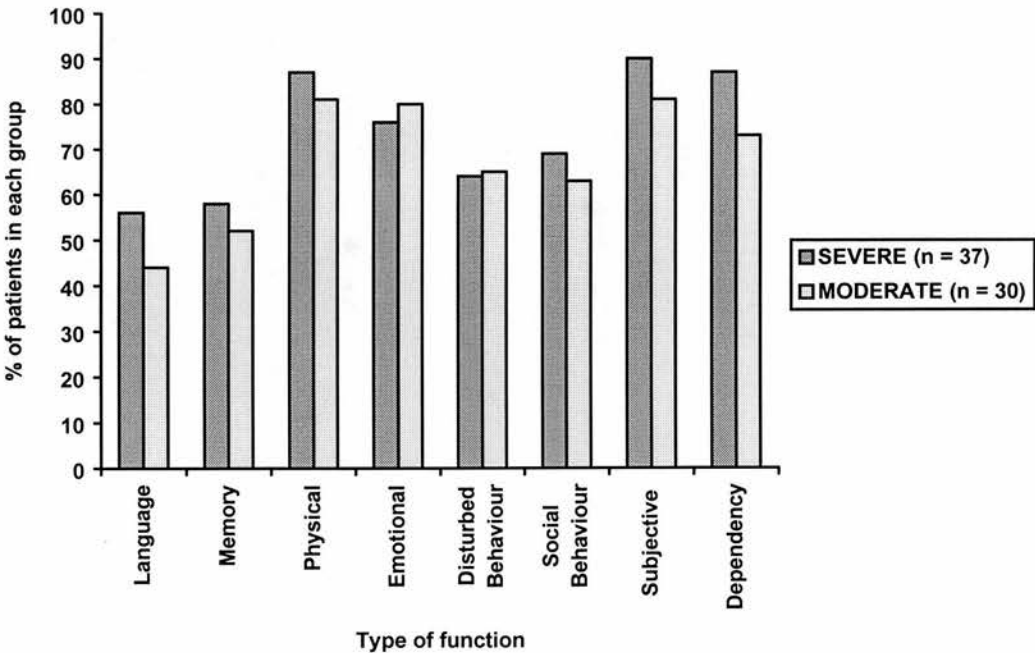
**Table 7.7** Most commonly reported individual symptoms at 24 months (% of patients affected)

Severe TBI (n = 28)	Moderate TBI (n = 27)
Employment affected (65%)	Less sociable (67%)
Passivity (65%)	Memory (59%)
Tiredness (62%)	Mood swings (56%)
Balance (58%)	Tension (52%)
Concentration (58%)	Impatience (52%)
Memory (58%)	Irritability (52%)
Tension (50%)	Concentration (52%)
Depression (50%)	Personality change (52%)
Personality change (50%)	Tiredness (48%)
Worse behaviour (50%)	Outbursts of temper (48%)

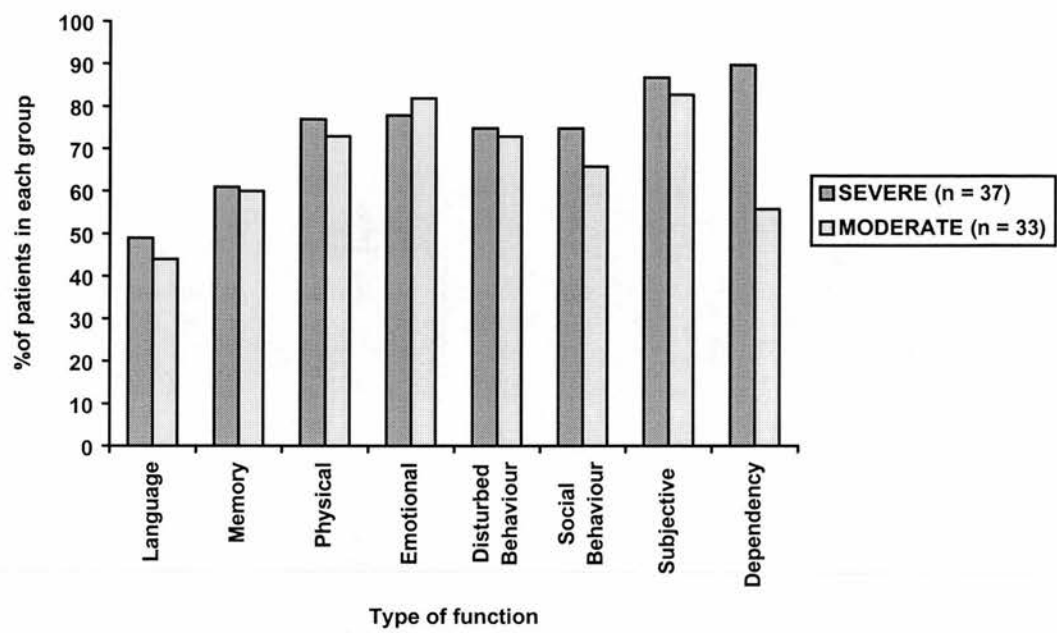
**Proportion of Patients with Disturbed Function**

In order to investigate the frequency of different symptom types, the proportion of patients reported to be experiencing one or more symptom in each of the eight categories was calculated, and the results are shown below.

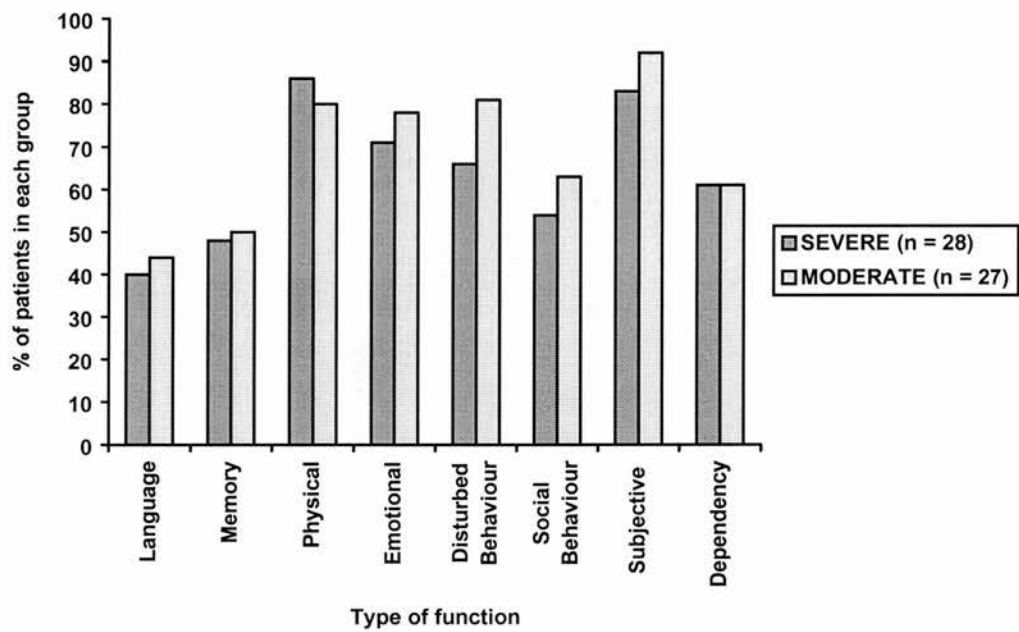
**Figure 7.1** Proportion of patients reported to have problems in the 8 categories of function at six months



**Figure 7.2** Proportion of patients reported to have problems in the 8 categories of function at 12 months



**Figure 7.3** Proportion of patients reported to have problems in the 8 categories of function at 24 months



The series of graphs (Figures 7.1 - 7.3) illustrates little difference between the severe and moderate TBI groups, and again demonstrates the high incidence of disturbed behaviour and emotional problems in the moderately injured group.

The biggest changes in the severe TBI group appear between 12 and 24 months post-injury, with marked improvements in the proportion of patients with reported disturbances of dependency and social behaviour.

The graphs reveal a different pattern for the moderate TBI group. The biggest changes are a decrease in the proportion of patients with reported problems of dependency and physical function between 6 and 12 months. Disturbed behaviour is reported in an increasing number of patients throughout the duration of the study whilst language and emotional disturbances remain relatively constant. Between 12 and 24 months there is a small increase in the proportion of patients with reported problems, especially in memory and subjective symptoms. This may be related to the fewer RQs returned at 24 months, and the possibility that those patients who were doing well did not return their questionnaires.

**Change Over Time**

The following table shows the mean number of problems reported at six, 12 and 24 months post-injury, to highlight any change over time.

**Table 7.8      Mean number of problems in each category in each group at six, 12 and 24 months**

Function (Maximum Value)	Severe			Moderate		
	6 mo. (n=37)	12 mo. (n=37)	24 mo. (n=28)	6 mo. (n=30)	12 mo. (n=33)	24 mo. (n=27)
Language (3)	1.22	0.94	1.04	0.63	0.88	0.70
Memory (6)	2.35	1.82	1.57	1.31	1.47	1.46
Physical (10)	3.72	3.39	3.67	2.67	2.33	2.88
Emotional (7)	3.36	3.63	2.91	3.37	3.85	3.56
Disturbed Behaviour (6)	1.94	2.53	2.00	1.66	2.06	2.23
Social Behaviour (3)	1.40	1.44	1.10	1.07	1.19	1.15
Subjective (7)	3.94	3.81	3.58	3.56	3.57	3.58
Dependency (7)	2.97	2.55	2.65	1.93	1.53	1.77
Total (49)	19.4	15.8	15.6	14.8	16.1	16.4

No overall emerging trend appears in the data: there is no consistent change over time, (either improvement or deterioration), in the number of symptoms reported by relatives. On each occasion, relatives of the severe TBI patients tend to report more symptoms of physical change and dependency than those of the moderate TBI patients, whilst relatives of moderately injured patients more commonly report emotional and behavioural changes.

It should be remembered that in some cases the relative or friend who has completed the questionnaire is not the same on different occasions although this is unlikely to be a major contributory factor (Hellowell and Signorini, 1997a). A more important factor is that the RQ data are not necessarily from the same patients at each assessment time. The lower return rate at 24 months was primarily caused by people failing to return the RQs, and it may be that these were people who had made a more complete recovery and felt that there was little point in completion of the RQ. This would lead to an overestimation of the degree of problems experienced by TBI patients. It is not possible to say if this was the case, because of the difficulties inherent in using the GOS scores assigned by GPs.

#### **RELATIVE'S QUESTIONNAIRE AND COGNITIVE ASSESSMENT**

In order to compare cognitive assessment with relative's reports, the correlation between the total number of symptoms reported by relatives (Sum RQ) and scores on the formal cognitive tests was calculated for all TBI patients. The results are shown in Table 7.9 overleaf.

**Table 7.9** Spearman correlations between Sum RQ and test scores in all TBI patients (\* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ )

	6 months (n=49)		12 months (n=48)		24 months (n=38)	
	$r_s$	sig	$r_s$	sig	$r_s$	sig
TOT	-0.37	*	-0.28		0.03	
FAST	-0.47	**	-0.52	**	-0.61	**
Boston naming	-0.28		-0.34		-0.72	***
MCST cats	0.03		-0.15		-0.41	
MCST errors	-0.14		-0.38	*	-0.72	***
TMT A	-0.40	*	-0.43	*	-0.35	
TMT B	-0.46	**	-0.58	**	-0.19	
Digit symbol	-0.32		-0.45	*	-0.15	
Digit span	-0.42	*	-0.46	*	-0.39	
Story immediate	-0.44	**	-0.56	***	-0.53	*
Story delayed	-0.48	**	-0.62	***	-0.60	**
Figure copy	-0.22		-0.26		-0.58	**
Figure recall	-0.31		-0.63	***	-0.90	***
Block design	-0.38	*	-0.26		-0.56	*

The table reveals an interesting pattern of results. The large number of correlations means that it is wise to focus on the highest correlations. Scores on the FAST were consistently significantly correlated with the total number of symptoms on the RQ, as were scores on the Story Recall test. The recall trial of the Complex Figure Test also correlated with Sum RQ, with a particularly strong association at 24 months.

### RELATIVES' STRESS AND REPORTED SYMPTOMS

The RQ has been used by other workers to investigate the relationship between relatives' level of stress and type of symptom (Brooks et al. 1986a). The current data were analysed to identify which problem types were most highly correlated with relatives' stress, and the results are shown overleaf. Again, the large number of correlations means that it is wise to concentrate on those with the strongest association.



**Table 7.10 Spearman rank correlations between stress and symptoms**  
 (\* =  $p < 0.05$  \*\* =  $p < 0.01$  \*\*\* =  $p < 0.001$ )

Function	Severe			Moderate		
	6 mo. (n=37)	12 mo. (n=37)	24 mo. (n=28)	6 mo. (n=30)	12 mo. (n=33)	24 mo. (n=27)
Mean Level of Stress	6.26	6.49	5.13	6.21	5.62	6.08
(s.d.)	(3.86)	(3.48)	(3.75)	(3.05)	(3.28)	(3.20)
Language	0.20	0.07	0.25	-0.02	0.13	0.10
Memory	0.38 *	0.34	0.65 **	0.18	0.53 **	0.28
Physical	0.53 **	0.27	0.26	0.27	0.28	0.50 *
Emotional	0.51 **	0.36 *	0.51 *	0.46 *	0.55 ***	0.62 ***
Disturbed Behaviour	0.62 ***	0.43 *	0.69 ***	0.18	0.54 ***	0.61 ***
Social Behaviour	0.57 ***	0.25	0.64 **	0.32	0.53 **	0.57 **
Subjective Symptoms	0.57 ***	0.44 *	0.57 **	0.44 *	0.49 **	0.76 ***
Dependency	0.62 ***	0.49 **	0.47 *	0.12	0.39 *	0.22
Total Symptoms	0.61 ***	0.66 ***	0.66 **	0.54 **	0.49 *	0.68 ***

The total number of symptoms (Sum RQ) correlated significantly with relatives' stress throughout the duration of the study, and in both patient groups. The areas of function most strongly correlated with relatives' stress are emotional and behavioral in nature. These findings are in agreement with those of other workers investigating severe TBI (McKinlay et al. 1981; Brooks et al. 1986a), and in the current study, are also supported in patients with moderate TBI.

**HEAD INJURY SYMPTOM CHECKLIST**

The Head Injury Symptom Checklist (HISC), described by Dikmen, Machamer and Temkin (1993), was used to record the patient's report of the frequency of the following 12 symptoms:

- Headaches
- Fatigue
- Dizziness
- Blurred vision

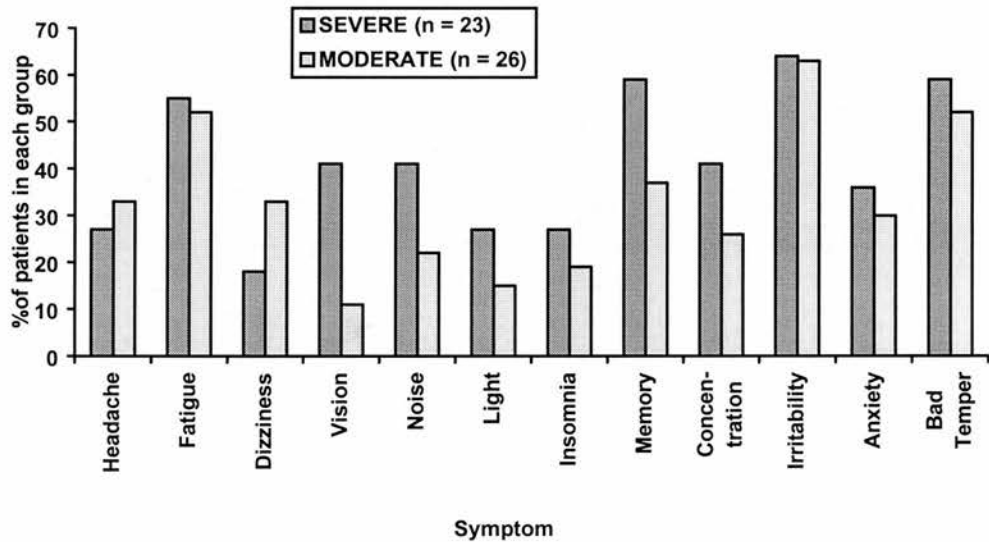
- Bothered by noise
- Bothered by light
- Insomnia
- Memory difficulties
- Difficulty concentrating
- Irritability
- Anxiety
- Loss of temper easily

Patients were questioned about each symptom in turn, unless they spontaneously described the symptoms. The following series of graphs illustrates the frequencies of each symptom reported in each group (Figures 7.4 - 7.6).

### Six Month Follow-up

At six months post-injury, headaches and dizziness were reported more frequently by the moderate TBI patients, but all other symptoms were more commonly reported following severe TBI. However, tiredness, memory problems, irritability and bad temper were reported by many patients in each group.

**Figure 7.4      Frequency of self-reported symptoms at six months post-injury**

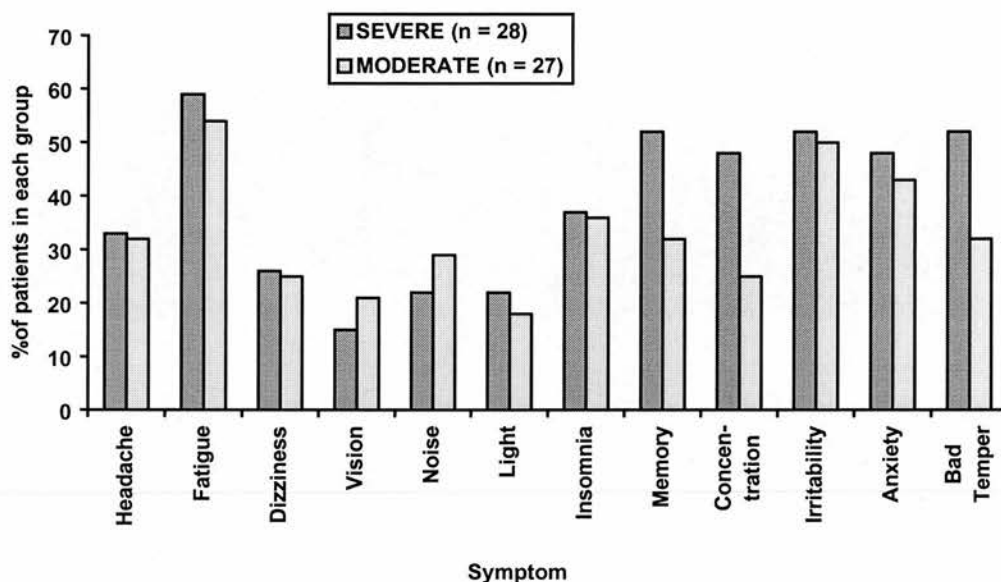


### Twelve Month Follow-up

At 12 months post-injury, memory and concentration problems were more common in patients with severe head injury, as was found in the analysis of the cognitive test data reported in Chapter 6; Section 6.1. Loss of temper was also more frequently reported

following severe TBI, but other symptoms were reported approximately equally in both groups.

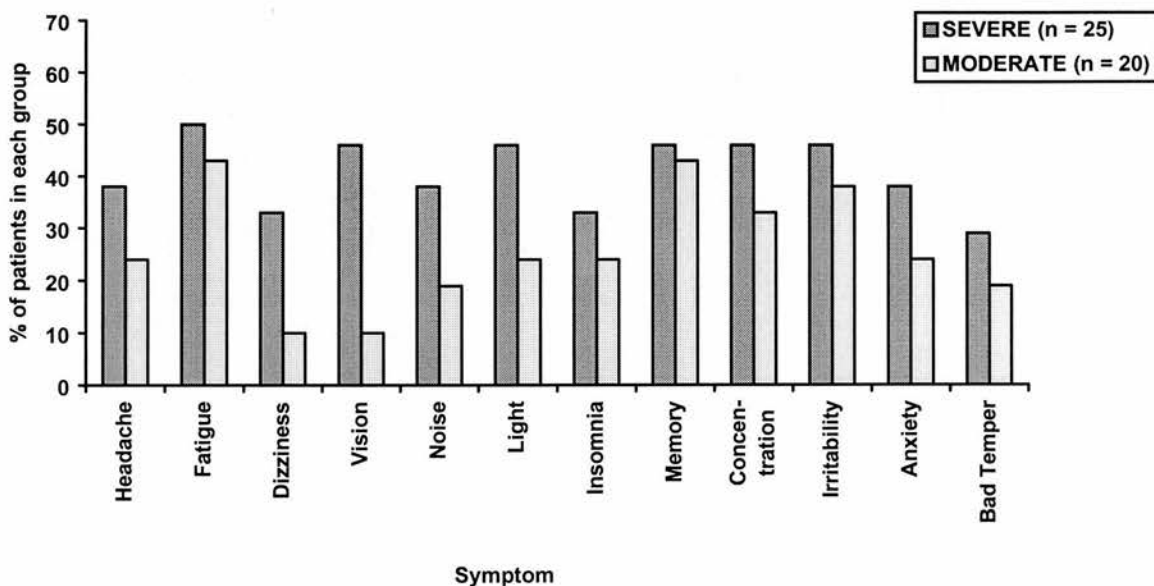
**Figure 7.5** Frequency of self-reported symptoms at 12 months post-injury



### Twenty-four Month Follow-up

At 24 months, symptoms were more frequently reported following severe TBI than moderate TBI, although all symptoms were reported by some patients within each group.

**Figure 7.6** Frequency of self-reported symptoms at 24 months post-injury



Fatigue and memory problems were the most common symptoms, with around half of the

patients in both groups reporting them, but various other problems were reported by many patients in the severe group.

**Change Over Time**

Comparing change over time, patients with severe TBI were reporting symptoms more frequently at 24 months post-injury, whilst those with moderate TBI appeared to be showing continued recovery in that many symptoms were reported less frequently at 24 months than at 6 or 12 months post-injury. One exception to this appears to be in the frequency of reported memory problems, which may result from those patients who are attending for assessment being those with the greatest degree of difficulty.

In order to look for significant differences between groups, a Chi-square test was carried out on each item of the HISC at each of the three assessment times.

**Table 7.11      Comparison of the frequency of individual symptoms between groups**

	6 months		12 months		24 months	
	$\chi^2$	sig	$\chi^2$	sig	$\chi^2$	sig
Headaches	0.418	0.518	0.009	0.925	0.627	0.428
Fatigue	0.208	0.648	0.439	0.508	0.040	0.841
Dizziness	0.511	0.475	0.006	0.937	3.111	0.078
Blurred vision	5.024	0.025	0.582	0.446	6.252	0.012
Sensitive to noise	1.481	0.224	0.487	0.485	1.385	0.239
Sensitive to light	0.861	0.354	0.073	0.787	1.751	0.186
Difficulty sleeping	1.588	0.208	0.210	0.646	0.265	0.607
Memory	1.598	0.206	1.569	0.210	0.004	0.947
Concentration	0.827	0.363	2.497	0.114	0.375	0.540
Irritability	0.071	0.790	0.019	0.891	0.073	0.787
Anxiety	0.827	0.363	0.475	0.491	0.627	0.428
Bad temper	0.583	0.445	1.569	0.210	0.385	0.535

The results of the HISC suggest a similar pattern to the RQ, in that there is no significant difference between groups, with the exception of blurred vision which was more frequent following severe TBI. Thus the moderate TBI patients and their relatives are reporting many long term symptoms typical of severe brain injury, despite the fact that their injury was not classified as severe.

## 7.2 Subarachnoid Haemorrhage

### RELATIVE'S QUESTIONNAIRE DATA

Although the RQ was designed for use with TBI patients, it was also felt to be appropriate for use with SAH patients. The questionnaire was changed slightly: the word 'illness' was substituted for the word 'injury', and questions pertaining to the cause of injury and compensation claims were omitted as these were not applicable to the SAH population. All other questions were identical in format and in order to those of the usual RQ.

### Return Rates

Return rates were recorded and are reported below. As with the TBI patients, the return rate dropped over time.

**Table 7.12      Return rates and reasons for non-return of RQs (%)**

	6 months	12 months	24 months
Completed	82	75	64
Not appropriate	5	5	5
Not returned	11	16	23
No-one to complete	2	2	0
Unable to trace	0	0	2
Other - out of the country	0	0	2
Patient had died	0	2	5

### Six, Twelve and Twenty-four Month Follow-up

As with the TBI patients, the mean number of symptoms per category was calculated for the SAH group at six, 12 and 24 months post-injury, and details are given in Table 7.13 overleaf. This shows a trend for improvement in the number of subjective symptoms and dependency of the patients, whilst disturbed behaviour and emotional symptoms increase in frequency over time.



**Table 7.13 Mean number of reported symptoms per category of function**

Function (maximum value)	Mean number of symptoms (s.d.)		
	6 months	12 months	24 months
	(n=36)	(n=33)	(n=27)
Language (3)	0.46 (0.66)	0.63 (0.87)	0.50 (0.95)
Memory (6)	1.74 (2.04)	1.47 (1.81)	1.79 (2.23)
Physical (10)	1.79 (1.88)	1.90 (2.20)	2.09 (2.41)
Emotional (7)	1.65 (1.72)	1.41 (1.59)	1.96 (2.06)
Disturbed Behaviour (6)	0.88 (1.24)	0.94 (1.46)	1.13 (1.42)
Social Behaviour (3)	0.69 (0.89)	0.63 (0.87)	0.65 (0.98)
Subjective (7)	3.26 (1.99)	2.90 (2.41)	2.39 (2.19)
Dependency (7)	1.60 (2.14)	1.86 (2.47)	1.46 (2.11)
Total (49)	12.1 (9.15)	10.5 (8.81)	11.3 (10.87)

The ten problems most commonly reported by relatives of the SAH group are shown in Table 7.14.

**Table 7.14 Most commonly reported problems following SAH**

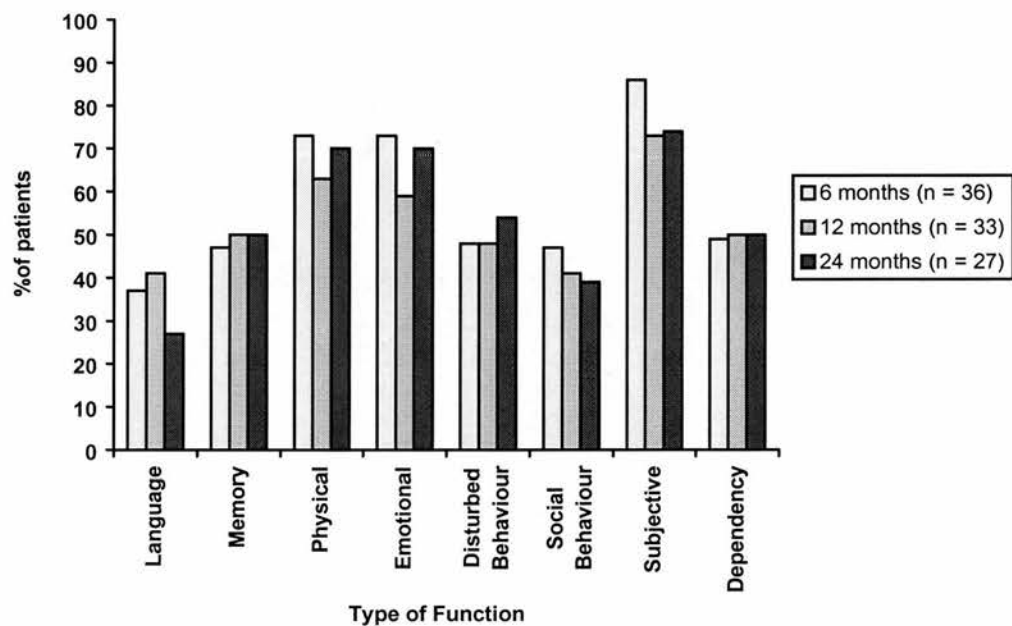
6 months (n= 36)	12 months (n = 33)	24 months (n = 27)
Tiredness (63%)	Tiredness (59%)	Tiredness (59%)
Passivity (61%)	Memory (52%)	Memory (56%)
Memory (50%)	Passivity (47%)	Passivity (46%)
Personality change (44%)	Balance (42%)	Sensitive to noise (44%)
Slowness (43%)	Decision making (41%)	Employment affected (43%)
Concentration (43%)	Slowness (39%)	Disturbed sleep (42%)
Balance (40%)	Less sociable(39%)	Impatience (41%)
Headaches (37%)	Headaches (38%)	Slowness (40%)
Anxiety (36%)	Sensitive to noise (38%)	Decision making (39%)
Impatience (36%)	Anxiety (36%)	Balance (35%)

The most commonly reported symptoms throughout the duration of the study were tiredness, passivity and memory problems, occurring in about half of the study sample, suggesting that these are common and persistent sequelae of SAH.

**Proportion of Patients with Disturbed Function**

The proportion of patients reported to be experiencing one or more symptom in each of the eight categories of function was calculated, and is shown in Figure 7.7. The proportion of patients with reported disturbed memory and dependency remains constant throughout the study. Subjective symptoms and social behaviour improve between 6 and 12 months, whilst disturbed behaviour appears to deteriorate between 12 and 24 months. Reports of physical problems and emotional behaviour fluctuate.

**Figure 7.7      Proportion of patients reported to have problems in the eight categories of function at six, 12 and 24 months**



The graph illustrates that a considerable proportion of the SAH group are exhibiting symptoms in each of the eight areas of function. This would suggest that it is relevant and appropriate for use with this patient group.

**RELATIVES QUESTIONNAIRE AND COGNITIVE ASSESSMENT**

As with the data from the TBI patients, the total number of problems reported on the RQ (Sum RQ) was correlated with the scores of the formal cognitive testing for the SAH group. There was only one significant correlation, between performance on TrailsA and Sum RQ at 24 months post-injury, but because of the large number of correlations carried out it is possible that this may be the result of chance alone. This lack of an association may be partly explained by the fact that the SAH patients' scores on cognitive assessment were at or

near a level expected in the general population. However, it also illustrates that despite reasonably good performance on formal assessment, patients' everyday lives remained influenced by their injury as reflected in their relatives' reports.

### RELATIVES' STRESS AND REPORTED SYMPTOMS

As with the TBI group, non-parametric correlations (Spearman) were calculated for level of stress and sum number of symptoms in each of the eight different categories of function.

**Table 7.15**      **Spearman rank correlations between stress and symptoms**  
 (\* =  $p < 0.05$     \*\* =  $p < 0.01$     \*\*\* =  $p < 0.001$ )

Function	Subarachnoid Haemorrhage		
	6 mo.	12 mo.	24 mo.
	(n=36)	(n=33)	(n=27)
Mean Level of Stress	3.97	3.63	3.83
(s.d.)	(2.66)	(2.79)	(3.21)
Language	0.45 **	0.36 *	0.51 *
Memory	0.24	0.41 *	0.42 *
Physical	0.44 *	0.44 *	0.52 *
Emotional	0.26	0.47 **	0.21
Disturbed Behaviour	0.24	0.58 ***	0.35
Social Behaviour	0.17	0.52 **	0.44 *
Subjective Symptoms	0.31	0.61 ***	0.51 *
Dependency	0.48 **	0.69 ***	0.50 *
Total Symptoms	0.49 **	0.59 **	0.71 **

The total number of symptoms reported by relatives was correlated with level of stress at a level of  $p < 0.01$  at all three assessment intervals. At 12 months, behavioural symptoms seemed to be more strongly correlated to level of stress than at either six or 24 months, but this pattern had changed at 24 months.

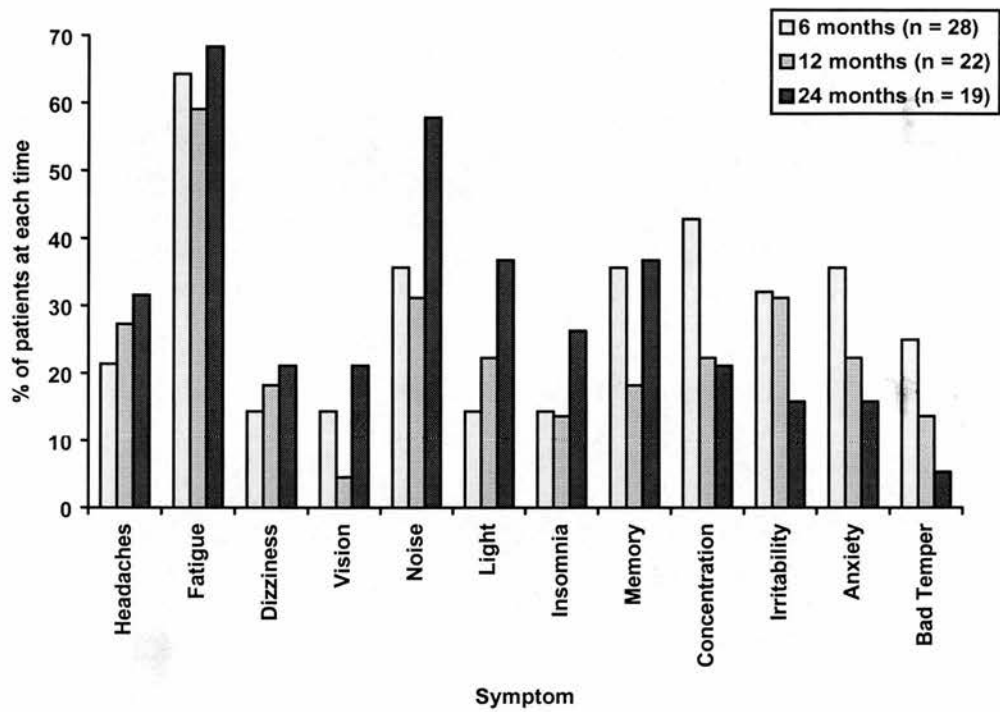
### HEAD INJURY SYMPTOM CHECKLIST

The HISC was used with the SAH patients to identify the incidence of self-reported subjective complaints.

**Six, Twelve and Twenty-four Month Follow-up**

The frequency and change over time of these reported symptoms are shown in Figure 7.8 below.

**Figure 7.8      Frequency of reported symptoms at six, 12 and 24 months**



The results of the HISC, shown in Figure 7.8, reveal the frequency and persistence of many symptoms following SAH. Although these symptoms are reported to be typical of post-concussion syndrome the present results would suggest that they may be typical of a broader category of brain injury.

**Change over Time**

There seems to be no change in the proportion of patients reporting tiredness, and an increase in the proportion reporting many other symptoms such as headaches, dizziness, and in particular, sensitivity to noise. However, emotional and/or behavioural problems such as irritability, loss of temper and anxiety are reported less frequently over time.

**7.3 Relative’s Questionnaire and other Outcome Measures**

**Traumatic Brain Injury**

The RQ was used because it was thought to give a useful insight into the ways in which the patient was affected by their brain injury. Spearman rank correlation coefficients were calculated between the Sum RQ, i.e. the total number of symptoms reported, and other

measures of outcome. This revealed the following correlations for the total TBI patient group.

**Table 7.16      Spearman rank correlations between Sum RQ and other outcome measures in TBI patients (\* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ )**

Outcome Measure	6 months		12 months		24 months	
	$r_s$	sig	$r_s$	sig	$r_s$	sig
GOS	-0.72	***	-0.57	***	-0.79	***
EEGOS total	-0.84	***	-0.70	***	-0.90	***
Anxiety	0.15		0.09		0.41	
Depression	0.38	*	0.35	*	0.47	*
Sum HISC	0.40	*	0.54	***	0.61	***
Overall test score	-0.56	**	-0.73	***	-0.89	* <sup>5</sup>

As might be expected, the GOS and EEGOS correlate most strongly with the Sum RQ. The RQ is used in the estimation of outcome using the GOS and EEGOS, and so it is logical that there should be a strong association between them. Although the prevalence of depression was approximately equal to that reported in primary care medical practice (Goldberg, 1995) depression as measured on the HAD correlated significantly, though weakly, with the Sum RQ at all three assessment times. There was no such correlation with anxiety. The prevalence of anxiety was higher in the TBI group than has been reported in primary care, but this does not seem to be related to the number of problems reported by relatives. In testing the patients, those who appeared anxious were often those with more insight into the nature of their difficulties, and the potential long-term problems which they might cause.

Again, a significant correlation between the number of symptoms reported by patients on the HISC and the Sum RQ was found at all three assessment times. This gives some validity to the self-report of patients, as this is often believed to be unreliable. The overall test score on cognitive assessment and Sum RQ were also significantly related at each assessment time, illustrating some association between cognitive function and functioning in everyday life.

### Subarachnoid Haemorrhage

The same analysis was carried out with the SAH patients, to enable a comparison of the

<sup>5</sup> The number of patients with complete neuropsychological assessment data and complete Sum RQs was lower than for other correlations; hence the lower degree of significance.



pattern of results. These are given in Table 7.17 below.

**Table 7.17** Spearman rank correlations between Sum RQ and other outcome measures in SAH patients (\* =  $p < 0.05$ ; \*\* =  $p < 0.01$ ; \*\*\* =  $p < 0.001$ )

Outcome Measure	6 months		12 months		24 months	
	$r_s$	sig	$r_s$	sig	$r_s$	sig
GOS	-0.71	***	-0.76	***	-0.73	***
EEGOS	-0.89	***	-0.86	***	-0.84	***
Anxiety	0.03		0.32		0.46	
Depression	0.22		0.56	*	0.62	
Sum HISC	0.21		0.63	*	0.74	*
Overall test score	-0.04		-0.21		-0.50	

Again, the GOS and EEGOS correlate most strongly with Sum RQ and this is to be expected because of the influence of the RQ on assessment of outcome using the GOS and EEGOS.

In the SAH group, there was no close association between Sum RQ and either anxiety or depression although the association between depression and Sum RQ was the closer. The number of items reported on the HISC and the Sum RQ correlated significantly at 12 and 24 months but not at six.

Unlike in the TBI patients, there was no relation between Sum RQ and overall test score. This may in part be due to the fact that the cognitive outcome of the SAH patients seemed to be either good or so poor that the patients remained unfit for assessment.

## 7.4 Comparison between TBI and SAH

### *Similarities*

Many similarities arise between groups when looking at the type and frequency of symptoms resulting from the brain injury.

Looking at the problems most frequently reported by relatives, tiredness and memory difficulties appear common in all patient groups. Passivity and slowness are commonly reported following severe TBI or SAH, whilst patients with moderate TBI are reported to be impatient and irritable.

Although patients with SAH in this present series were considered to have a less severe brain injury than the TBI patients, the frequency of self-reported symptoms such as memory problems and fatigue was of a similar order to those reported by the TBI groups.

### *Differences*

Despite the difference in severity of injury and the different causes and mechanisms of brain insult, there are few differences in the number and type of symptoms reported by the patients' relatives.

Perhaps the most noticeable difference is the higher frequency of behavioural and emotional symptoms reported by relatives of the moderate TBI patients, whilst relatives of the severe TBI patients report more subjective symptoms and change in the level of dependency. Relatives of the SAH patients report subjective symptoms and memory difficulties as the most commonly occurring problems post-haemorrhage.

There is also a difference in the recorded level of stress with relatives of TBI patients reporting a mean level of around 6 on a scale of 1 to 10, irrespective of the severity of injury. Relatives of SAH patients report level of stress of around 3 or 4 on the same scale. The reason for this difference is not apparent. It may be the case that relatives of patients with SAH are relieved that the person has survived and are thus more tolerant or better able to cope with changes in the person's behaviour. Alternatively it may be associated with the fact that the severity of injury was not as great in the SAH patients, and so the patient's condition was less likely to be life-threatening. Another explanation may be that the SAH patients are in more stable relationships, partly because they are slightly older than the TBI groups, and partly because they have a more stable lifestyle. The TBI patient groups have a higher proportion of risk-takers and substance abusers than the general population and this may also influence the degree of stress reported by relatives.

## Chapter Eight      Discussion

The principal purpose of this study was to provide a detailed investigation of outcome following moderate or severe TBI, particularly in relation to cognitive function. A secondary aim was to compare these findings with a group of SAH patients. The results demonstrate that the effects of acute brain injury from either cause can be profound both for the individual and their family. In most cases recovery is incomplete and many remain seriously affected by their injury two years later. Few return to their former level of employment and most relatives report lasting changes as a result of the injury.

Discussion will follow the format of the thesis, concentrating initially on methodological issues. The discussion of the results encompasses both the cognitive assessments and the RQ information to allow comparisons and contrasts to be made between the perceived outcome and the experience of the primary carer.

### 8.1 Methodological Difficulties of Group Studies

It has been suggested that there are three important factors to be taken into account when carrying out group studies: patients must be capable of being tested; patients must be willing to be tested; and testing must not interfere with other clinical examinations (Shallice, 1988). This represents an ideal and each of these recommendations is problematic when considering a study of the present patient population. The following discussion highlights the difficulties inherent in group studies of brain-injured patients, the associated problems with methodology and design, and how these issues have been addressed in the current study.

#### **Population Description**

In any clinical study, it is essential that the population from which a sample is drawn is adequately described, because some variability will arise as the result of differing admission and management policies (Jennett, 1996).

In an attempt to provide an accurate description of the characteristics of the current patient sample, many demographic details were collected. Although it would have been ideal to look at a representative sample of the entire TBI population, only patients with moderate or severe injury were studied. This reflects the admission policy of the RNU, whose patients consisted principally of people transferred from other hospitals with moderate or severe injuries. The few exceptions were individuals with mild TBI from local hospitals admitted for observation and some from outlying hospitals who had shown neurological deterioration

some time after an ostensibly minor injury. Inclusion of such cases would not be representative of the mild end of the spectrum of TBI. In contrast the policy for SAH cases was that all were routinely transferred to the RNU so that they reflect the total population of such patients.

### **Control Groups**

As previously discussed, the head injured population is not a representative cross sample of the population at large. The ratio of men:women is of the order of 3:1 and most patients are in the age range 15 - 40 years at the time of their injury. In addition they differ in psychosocial characteristics. A higher proportion are described as risk-taking, alcohol or drug abuse is common and a disproportionate number come from lower income groups (Kraus and McArthur, 1996b). The SAH population is a much more representative cross-section of the general population, mainly as a result of the aetiology of the condition.

A number of workers have advocated the use of control groups in studies of TBI to address this over-representation of young people (especially men) and the psychosocial characteristics of the patient population (Dikmen and Levin, 1993). Ideally, control groups and the experimental groups should differ only on the fact that the TBI group have had a brain injury, and so in the case of TBI they should be:

- an 'at risk' group;
- have had a significant trauma which is potentially life-threatening;
- have acute physical injuries leading to hospitalisation;
- have significant disability (McKinlay and Brooks, 1984).

However, there are a number of inherent difficulties with this. The main problem is in finding a suitable population to act as controls, who are matched to the head injured population on a number of different attributes. In some studies, orthopaedic patients have been used to gather control data (Brooks and Aughton, 1979b; McMillan and Glucksman, 1987). The reasoning for this was that patients with orthopaedic injuries may have similar lifestyles: they fall in to the 'at risk' category and may have gained their injuries from similar sorts of accident to the head injured population e.g. RTAs, sporting accidents, or assaults. However, orthopaedic injuries are rarely life-threatening and hospitalisation is usually limited to a few weeks in most cases. Brooks (1991) recommended people with paraplegia or tetraplegia as a result of spinal cord injury as a closer match to TBI. Spinal cord injuries are much less common and were not available in this study, as they are transferred to a national unit in Glasgow. Another factor which makes neither of these

groups adequate controls is that, as they suffer no cognitive deficits, repetition of assessments is likely to show completely different practice effects than in the brain-injured.

Other approaches include the use of a friend of each patient as a control, because they are likely to have similar demographic and psychosocial characteristics or advertising for controls from a newspaper, and matching them on a number of different demographic variables (Hall and Bornstein, 1991). Although it is possible to use patients with a similar socio-economic background and match them for age and sex, there are many other variables which will not be controlled, such as having recently sustained a life-threatening trauma. Other workers have used psychiatric patients as controls for the head injured (Mandleberg and Brooks, 1975) although the usefulness of this has since been questioned (Brooks et al. 1984).

In addition to identifying a control group of young adults with similar psychosocial characteristics to the head injured, the response rate in such a group is likely to be low, as illustrated by the experience of Rosenbaum and Najenson (1976), who reported less than 50% responding.

To some extent, the purposes of the study determine whether or not a control group is needed (Brooks, 1991). As the present study was aimed at addressing the extent and nature of cognitive impairments following moderate versus severe TBI, and the change in those impairments over time, it was felt unnecessary to include a control group. The inclusion of the SAH group was simply to enable tentative comparisons to be made between groups as outlined previously, and as SAH patients tend to be a much more representative cross-section of the general population, the need for a control group is less.

### **Selection Criteria**

Most previously reported studies have used various selection criteria to define particular patient groups, and the results obtained are therefore only representative of those groups. Typically cited examples are exclusion of patients with a history of alcohol and/or drug abuse, psychiatric illness, or a previous TBI (Levin et al. 1979a; McMillan et al. 1996). The aim of excluding such patients from a study is to isolate the deficits resulting from the current brain injury alone.

Clifton et al. (1993) provide useful data by reporting that 52% of their sample did not complete neuropsychological assessment for the following reasons: 28% were excluded on the grounds of substance abuse; 15% were untestable; 11% had had a previous TBI; and



46% were 'geographically unavailable'. Patients who drink heavily, patients who have experienced premorbid psychiatric disorders, and patients who have suffered head injuries prior to their current admission to hospital and experience impaired cognitive functioning as a result of that earlier injury, make up a small but consistent proportion of the head injured population and to exclude them from the study would be to bias the sample from the usual distribution of TBI patients.

If a group study is to produce interpretable data then selection criteria, which limit the patients entered into the study, must be well-defined. However, few studies provide a clear definition of what is considered as 'alcohol abuse'. If the researchers are reliant on patients' self-report of drinking habits, then this information is likely to be unreliable. Likewise, definitions of previous psychiatric disorder and of significant previous head injury may be similarly vague.

If we are to use a sample which is truly representative of the head injured population, then it is not appropriate to exclude these patients from the study. In the present study patients were a group of consecutive admissions to the RNU<sup>6</sup> rather than those meeting criteria which would lead to another selection bias. No patient was excluded on the grounds of age, past history of alcohol or other drug abuse, or previous episodes of psychiatric disorder.

### **Attendance Rates**

Follow-up of patients with head injury is notoriously difficult (Brooks and Aughton, 1979b). Conkey (1938) was able to follow up only four patients at a year, from a group of 25 seen early after injury. More recent studies cite follow-up rates of the order of 25% (Clifton et al. 1993) to 48% (Ponsford et al. 1995a). Other workers include a selection criterion such as 'completed neuropsychological assessment' (Uzzell et al. 1987b) but this obviously constitutes an important bias.

A number of suggestions have been put forward to try and improve follow up rates. Some workers recommend reducing the duration of follow up (Gronwall and Wrightson, 1975; Rimel et al. 1981). This may be particularly pertinent when following up patients with mild or minor head injuries who may feel that they have fully recovered so that follow up is unnecessary. In the present study the attendance rate fell between 12 and 24 months post-injury, suggesting that duration of follow up may be important irrespective of severity of injury.

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<sup>6</sup> The admission policy of the RNU influenced the use of severity of TBI as the only selection criterion.

Brooks et al. (1984) recommend that one way to reduce drop out from research studies is to be prepared to visit people in their own homes when necessary. In order to optimise follow-up rates, home visits were carried out if requested by the patient, and were especially common in cases where the patient lived a considerable distance away from the hospital and had to rely on public transport.

Another potential difficulty with the current study was that many patients were seen for clinical review appointments for many months post-injury. This was particularly true in cases where the patients' injuries were severe, where there were complications, or where they had been treated in the acute rehabilitation unit. In some cases, the patients had so many appointments that they were unable to attend them all, and at such times their clinical appointments took priority. Some patients were also involved in other research projects, and although the timing of assessments of the other projects was chosen so as to differ from those reported here, some patients were unwilling to participate in more than one study.

### **Timing/Frequency of Assessments**

Some studies investigating patients' outcome have taken place at fixed time intervals such as one, three, six or 12 months post injury (Levin et al. 1979a; McKinlay et al. 1981; Rimel et al. 1982; Dikmen et al. 1987), with most concluding follow-up at the 12 month assessment (Brooks et al. 1984). A number of studies have included patients at a wide range of time intervals post injury, thereby adding confounding variability to the results (Stuss et al. 1985; Vogenthaler et al. 1989; Stenhouse et al. 1991). Others report follow-up assessments based on time since first neuropsychological assessment (Dikmen et al. 1983).

Previous work has often focused on follow-up at six months post-injury. This was believed to be the time at which most of the patients' recovery had occurred and therefore an appropriate point in the recovery process at which to estimate outcome. Choi et al. (1994) found improvement in outcome over the first six months following severe TBI, after which time 'outcome tends to stabilize'. They found little change between 6 and 12 month outcome when classified as either favourable (good recovery or moderate disability) or unfavourable (severe disability, PVS, or death), suggesting that six months post-injury would be a suitable end-point for clinical trials. However, the needs of some clinical trials may be different from those of more detailed outcome studies, and such gross outcome categories are insensitive to all but the most dramatic of improvements.

A few studies have looked at longer term outcome (Lewin et al. 1979; Thomsen, 1984; Brooks et al. 1986a), and found evidence to suggest that although long-term deficits are

often present, improvement may continue for many years post-injury. This has important implications in that it would suggest that any study of recovery and outcome should use well-defined predetermined assessment times. Thus, specific assessment times were used in the present study, with the timing of assessments guided by the experience of other reports. Brooks et al. (1984) comment that

‘the more complex the function, the longer the total duration of follow-up necessary’ (p75), and ‘the more severe the injury, the more likely more complex functions are to be affected, the slower they are going to recover..... with recovery being fast early after injury and slowing down very soon’ (p76).

The timing of assessments in the present study was chosen prospectively to be six, 12 and 24 months post-injury, because of the severity of brain injury of the patients.

### **Practice Effects**

If patients are seen and assessed at a number of different times post-injury, it follows that any improvement in their performance at these tasks may be confounded by practice through repetition. Patients may remember what they will be asked to do, develop strategies to improve their performance, or benefit from procedural learning.

In order to get round the problem of practice effects, a number of workers have advocated the use of control subjects to act as a baseline with which to compare the performances of head injured patients although the inherent difficulties associated with this have already been addressed.

An alternative method which has been developed to counteract to some extent the effects of practice is the use of ‘parallel forms’. Parallel forms of a test are two versions whereby the instructions are identical, but the material is different and adjudged to be of a comparable level of difficulty. A well-established example of supposedly parallel forms of a test consists of two forms of the Complex Figure Test. The same instructions are used, and the alternative figures are reported to be of equivalent complexity (although not equivalent difficulty; Lezak, 1995).

There are two problems with using parallel forms: for many widely used standardised tests there are no parallel forms available; and for those tests which have supposedly parallel forms, there are often differences in the level of difficulty of the two versions, so that they are not truly parallel. In the present study, parallel forms of the Story Recall task and the Complex Figure Test were used at alternate assessment intervals. However, the difference

in difficulty of the parallel forms of both tests made interpretation of change over time difficult.

### **Duration of Assessments**

Patients commonly report problems with tiredness and sustained concentration so any assessment should not be too long and arduous for the patient. A number of reports appear in the literature offering recommendations for the maximum length of an assessment session. Clifton et al. (1992) recommended that the maximum length of a neuropsychological assessment session should be 1.5 hours. Kreutzer et al. (1993), whilst recognising and identifying a number of reasons for limiting the test session, recommended that 'for the average patient, completion of tests should be accomplished within 2 hours'. Other workers have used several sessions to complete testing, but such a method was impractical in the current study. The length of the session was kept to 1.5 hours to minimise effects of fatigue, and to encourage patients to return for further assessments.

### **Testability**

A number of reports have alluded to the fact that as medical and surgical treatments progress, the number of patients who survive severe head injuries also increases. This leads to a number of patients who survive the initial injury but who have very severe residual impairments, and who are likely to remain dependent for the rest of their lives. More severely affected patients may be unable to complete formal neuropsychological assessment because of the extent of their disability (Clifton et al. 1993; Kreutzer et al. 1993). This was confirmed in the present study, and whilst the number of patients who were unfit for assessment decreased during the duration of the study, a proportion of both the TBI and SAH patient groups were still unable to participate in cognitive assessment at 24 months post-injury.

Thus this discussion highlights some of the problems in complying with Shallice's three recommendations for group studies (Shallice, 1988). Firstly, brain injury is known to affect cognitive function and recent studies have reported that as the survival rate improves, so does the number of patients who survive but who remain severely affected by their injury. Therefore it is reasonable to expect a proportion of the study sample to be unfit for any detailed neuropsychological assessment. Secondly, previous studies report that patients with head injury are notoriously difficult to follow up, and exceptional effort will be needed to maximise the follow-up rate. Finally, because of the nature and severity of injury and the

improvement in out-patient and rehabilitation services, it is likely that some patients will have clinical appointments which overlap, and may interfere, with the timing of the study.

## 8.2 Acute and Demographic Data

The recruitment period during which TBI patients were entered into the study was from November 1992 until April 1994 inclusive. This period was much longer than had been predicted, because the original study proposal was based on figures from 1988 - 1990 inclusive. Over that period, the numbers of annual admissions to the neurosurgical unit following moderate or severe head injury were 102 severe head injuries, and 95 moderate head injuries per year excluding fatalities. Since then, the number of patients admitted to the unit has dropped markedly. The precise causes of this are not clear. The increasing use of stringent safety rules and regulations may have led to a decrease in the incidence of head injury. New cars are manufactured with more advanced safety features, protecting the vehicle occupants from injury in the event of an RTA. The promotion of preventive measures such as the anti-drink/driving campaign may have also contributed. Although assaults are still a relatively common cause of TBI, there has been a reported increase in the use of knives which may lead to a decrease in the overall incidence of assault-related TBI.

The study was also intended to investigate the similarities and differences between those patients who suffered brain injury resulting from trauma or from aneurysmal SAH. The reason for making this comparison is that although the initial injury mechanisms differ, there are many secondary insults to the brain which are common to both patient groups. For example, the formation of a haematoma, or hypoxic injury to the brain are common secondary injuries following either TBI or SAH. It was believed that the secondary insults which were common to both groups would lead to some impairments or symptoms which would also be common to both groups.

### **Secondary Insult Data**

Following admission to hospital, a number of TBI patients were monitored in the ITU. A microcomputer based monitoring system was used to record physiological data at one minute intervals, to indicate the presence of secondary insults such as raised intracranial pressure, hypotension, hypertension and hypoxia, using the methodology reported by Jones et al. (1994). Because injury to the brain is known to be a process rather than a single event, improved early management should lead to improved outcome.



Of the patients entered into the study, 31 (58%) severe TBI patients and 9 (21%) moderate TBI patients were monitored. The difference between groups is attributable to the limited amount of monitoring equipment which tends to be used with patients who suffer more severe initial injuries and who are considered more likely to experience severe secondary insults to their brain.

Eight channels of physiological data were recorded. These were (with criterion levels for presence of insult in parentheses):

- Raised intracranial pressure ( $\geq 20$  mmHg)
- Hypotension ( $\leq 90$  mmHg)
- Hypertension ( $\geq 160$  mmHg)
- Cerebral perfusion pressure ( $\leq 55$  mmHg)
- Hypoxia  $\text{SaO}_2$  ( $\leq 90\%$ ) or  $\text{PaO}_2$  ( $\leq 8.0$  kPa)
- Pyrexia ( $\geq 38^\circ\text{C}$ )
- Tachycardia ( $\geq 120$  bpm)
- Bradycardia ( $\leq 50$  bpm)

There are many difficulties associated with any form of analysis of these detailed minute-by-minute data. The data collection is strongly biased toward the more severely injured patients, and the data reflect secondary insults in surviving patients only. The secondary insults may combine interactively, and an optimal method of analysing these complex physiological data is still under development by other workers within the department and elsewhere. Further analyses of relationships between outcome measures and secondary insult indices need to be carried out in both TBI and SAH, but the overwhelming methodological issues in devising such indices need to be addressed before this can be done. Consequently, analyses of relationships between outcome and the detailed secondary insults are not presented here, although basic analysis of the more crude measures of complications and outcome has been presented.

### **Rehabilitation**

The current study showed that a higher proportion of the severely injured TBI group received acute in-patient rehabilitation than those who were moderately injured. This has also been reported in other studies (Aronow, 1987). However, Rimel et al. (1982) have argued that patients with severe TBI are more likely to have sustained irreversible brain damage than those with moderate TBI, and that more attention should be directed toward

those with moderate injury. Although Rimel's argument was referring to the early stages of management, it could equally apply to later stages of rehabilitation.

As discussed in Chapter 4 Section 4.3, 45% of severe, 26% of moderate TBI patients, and 32% of SAH patients were treated in the acute rehabilitation unit following discharge from the RNU. This is despite the fact that those patients with SAH were believed to have suffered less severe brain injury than the TBI group. Access to acute in-patient rehabilitation is dependent on factors such as the availability of beds and, in some cases, funding from an appropriate source. The proportion of patients receiving acute rehabilitation is also influenced by the fact that some patients discharge themselves against the advice of the medical staff. This is particularly the case in TBI patients who often have no recollection of the accident which caused their injury, little appreciation of difficulties they have, and no idea why they are in hospital. During the period of confusion when they are coming out of PTA they may take their own discharge because of a lack of recollection of the explanations they may have been given concerning their accident and injuries and the consequences of these.

Unless one adopts the stance of Rimel et al. described above, the fact that a significantly higher proportion of patients with severe injury received intensive acute rehabilitation than patients with moderate injury seems justified according to the GOS and neuropsychological test measures in this study, although not the questionnaire measures. Nevertheless, the data would suggest that the need for rehabilitation in patients with moderate head injury is not being adequately addressed. Obviously, there are limitations on rehabilitation resources, but the results presented here would suggest that rehabilitation should be available to all TBI patients, regardless of whether the initial injury is classified as moderate or severe according to traditional criteria. Better methods of early prediction of late outcome are still required to allow better focus of rehabilitation input where it is most needed.

### 8.3 Outcome Data

Clifton et al. (1992) suggest that outcome measures should be clinically relevant, have unambiguous definitions and satisfactory interrater reliability and be sensitive to change. They suggest that both the Glasgow Outcome Scale (GOS) and Disability Rating Scale (DRS) fulfil these criteria making them suitable measures for use in clinical trials, or in studies where patient populations need to be compared. In the present study, a scale was needed in order to compare overall outcome between groups, and the GOS was chosen because it is so widely used in both TBI and SAH patients.

### **Glasgow Outcome Scale Scores**

The data revealed a difference in outcome between the severe and moderate TBI patients, with the severe patients having a significantly worse outcome throughout the two year period following injury. However, there are methodological difficulties to consider. In cases where the patients refused to participate in the study, GOS scores were allocated by their GPs, a method known and accepted as being unreliable in that GPs are more likely to overestimate the patient's level of recovery (Anderson et al. 1993). In the present study, GP GOS scores were used for three patients in each group at six months post-injury, for four severe and three moderate patients at 12 months, and seven severe and six moderate at 24 months post-injury. It was hoped that any overestimate of level of recovery arising from the use of GP GOS scores should be approximately equally distributed between groups and therefore have a minimal influence on the degree of difference between groups.

Patients in the current series appear to have been more disabled than those in other reports of outcome following moderate or severe TBI. Jennett et al. (1981) reported data on outcome at six months after severe TBI, from three studies with a total data bank of over 1000 patients. In the conscious survivors ( $n = 655$ ), the rates of good recovery at six months were 40%, 44% and 47% and severe disability 20%, 21% and 19% in the three studies. In the present study, the rate of good recovery was much lower than this (25%), and the rate of severe disability higher (35%). Roughly the same proportion were classified as moderately disabled (35 - 40%) in the current study as in the report of Jennett et al.

Teasdale (1997) reported six month outcome using the preliminary findings of the European Brain Injury Consortium (EBIC). Of 1005 patients admitted into 67 European centres during a three month period in 1995, GOS scores were available on 796 (79%) at six months. Thirty-one percent of patients had died. Of those who survived, 4% were vegetative, 23% severely disabled, 29% moderately disabled, and 44% were classified as having made a good recovery. Again, this study shows a better outcome for severe TBI patients than in the present study. Although the EBIC study reports outcome in a large number of severe TBI patients, the proportion of missing data is quite high, and no details of how the GOS scores were collected are given. This could be potentially problematic as the reliability of the GOS varies according to the method by which it is used (Anderson et al., 1993; Hellowell, Signorini & Pentland, submitted). When reporting GOS scores, details of the method by which they were derived should be described and the reliability established.

There are difficulties in relating the findings in the SAH patients to other reported series. Some studies only describe patients who have been treated surgically (Taylor et al. 1991), whilst others have restricted their outcome findings to those with aneurysms at specific sites (Rinne et al. 1996). One of the few studies to provide comparable information is that of Maurice-Williams and Kitchen (1994). Looking at the one year outcome of the 76 survivors of their most recent cohort of 100 patients, 92% were classified as 'good recovery' with 5% moderately disabled, and 3% severely disabled. Again, these figures suggest a better outcome than found in the present study but there are no details of how the GOS information was collected.

Return to work has been used by a number of authors as a measure of outcome (Brooks et al. 1987b; Crepeau and Scherzer, 1993; Ponsford et al. 1995b). However there are many factors which influence a patient's return to work, such as the patient's employment status prior to injury or the willingness of their employer to accommodate the patient's needs. Currently, the rate of unemployment in the community at large is high and competition for jobs is fierce making it more difficult for patients to return to work if they are made redundant. Nevertheless, the results of the present study show a much reduced rate of employment in both TBI groups and the SAH group, which cannot be accounted for by extraneous circumstances alone and must be at least partially attributable to brain insult.

### **Glasgow Coma Scale versus Duration of Post-traumatic Amnesia**

The study also addressed the importance of two commonly used measures of severity of injury as potential indicators of outcome. Comparing patients following moderate or severe TBI as determined using GCS on admission to hospital, there is some degree of correlation with GOS outcome, but the results support the use of PTA as an indicator of severity, and a prognostically useful indicator of likely outcome.

In order to compare cognitive outcome with severity of injury, correlations were carried out between duration of PTA, GCS on admission and overall test score. Both GCS and PTA correlate significantly with overall test score at six months post-injury ( $r = 0.42$ ;  $p = 0.022$ ; and  $r = -0.46$ ;  $p = 0.011$  respectively). At 12 months only the correlation between test score and GCS is significant ( $r = 0.59$ ;  $p = 0.001$ ), whilst at 24 months only the correlation between test score and PTA is significant ( $r = -0.67$ ;  $p = 0.008$ ).

Wilson et al. (1993) suggest one possible explanation for the inconsistent relationships between PTA, coma and outcome is that:

“coma and PTA reflect different aspects of brain damage and that they are thus not equivalent” (p198).

They identified a small group of patients with a short duration of coma but long PTA who had evidence of more extensive hemispheric damage on acute MRI scans. Presumably such factors contribute to the pattern of results found in the present study. Inevitably, results of the present analysis did not include patients who were unfit for cognitive assessment. Considering the two measures of severity of injury, 17.6% of those who were unfit at six months had sustained a moderate TBI as defined using GCS on admission, whilst using duration of PTA all unfit patients were classified as having sustained a severe injury (duration of PTA was 1 to 4 weeks in 11.8%, and more than 4 weeks for the remainder).

### **Edinburgh Extended Glasgow Outcome Scale**

The present thesis describes the development of a new outcome scale, the EEGOS. This would seem to have a number of advantages in that it enables a more detailed description of outcome than the original GOS, and is apparently more sensitive to change.

One possible advantage of using a more detailed outcome measure than the GOS may be that it encourages raters to look for and identify patients' problems more carefully and accurately. In the study of Brooks et al. (1986), outcome of the same patient group was estimated by two independent raters using both the GOS and an extended version of the GOS, in which each category for conscious survivors was separated into two: either high or low (which enabled the scale to be easily collapsed back into the GOS). However, when using the extended GOS, the raters estimated patients' outcome to be much poorer than when using the original GOS. This would suggest that when forced into making a more detailed discrimination of outcome, the raters gave more weight or more thought to the patients' difficulties. The EEGOS requires consideration of the nature of different types of deficit, so it also may lead to a more accurate description of the patient's difficulties and disability. The EEGOS is yet to be tested by asking GPs to use it to estimate their patients' outcome and this may lead to a loss of reliability as has already been found with the GOS (Anderson et al. 1993). Alternatively, it may be that by detailing different types of functioning it will encourage a more thorough consideration of the patients' outcome than when using the GOS. The present scale has been shown to have a similar level of reliability to the GOS, and these preliminary results justify further investigation and development of the scale. In particular, reports from the pilot studies have highlighted the limitations of the behavioural and emotional scale (see Chapter 5; Section 5.4).



A comparison of the pattern of recovery in different patient groups using the EEGOS showed the following.

#### *Severe Traumatic Brain Injury*

The biggest change in the severe TBI group is an improvement in behaviour between 6 and 12 months, followed by a subsequent and bigger deterioration between 12 and 24 months. Cognitive and physical function appear to vary in this group, with some patients improving and a similar proportion assessed as deteriorating.

#### *Moderate Traumatic Brain Injury*

The group of moderate TBI patients shows the biggest degree of improvement between 6 and 12 months, particularly in cognitive and physical function. This is followed by a deterioration between 12 and 24 months. Level of behavioural function appears to fluctuate over the two year period.

#### *Subarachnoid Haemorrhage*

The SAH patients show a marked deterioration in behaviour throughout the period of the study, although this behavioural deterioration does not render them dependent. There is a gradual improvement in cognitive function, and an overall trend for improved physical function with an increase in the proportion of patients classified as having made a 'good recovery'.

This brief resumé of the results of the EEGOS assessments illustrates the prevalence of behavioural problems in all patient groups. This is perhaps most surprising in the group of SAH patients, where changed behaviour has not been commonly reported in the past. One possible explanation of this is that the types of behavioural changes following SAH may be more subtle than in the TBI patients, or of a different nature. The results of this current study would suggest that further investigation of behavioural change following SAH is warranted.

Behaviour problems are typically associated with TBI patients, and there is evidence to suggest that although the proportion of patients with maladaptive behaviour does not increase over time, the frequency and severity of behaviour problems increases in those in whom such problems are present (Johnson and Balleny, 1996). Johnson and Balleny found an increase in problem behaviours over a three year period post-injury, with a 'dramatic increase' in aggression (p178). Behavioural problems in their sample occurred irrespective of severity of injury. They suggest two possible reasons for the increase in disturbed

behaviour: the relatives fail to notice or report behavioural problems soon after injury; or the patients' level of frustration increases and their behaviour worsens with increasing awareness of the limitations caused by the brain injury. Another possible explanation of the increase in reports of disturbed behaviour may be a result of reduced tolerance in the relatives, following a gradual erosion of patience and a lack of respite. Whatever the reason, there has been little systematic investigation of behaviour following brain injury, and reports which do exist are difficult to compare because of the lack or inconsistency in objective measures of behavioural change. The current results illustrate the high prevalence of changed behaviour in the patient samples here, and the finding that behavioural problems worsen with time since injury, as reported by other workers.

## 8.4 Cognitive Assessment<sup>7</sup>

### **COGNITIVE ASSESSMENT: COMPARISON BETWEEN TBI AND SAH**

As discussed earlier, follow-up of TBI patients is notoriously difficult. The assessment rate achieved in the current study was comparable to those reported by other workers. There were various reasons for non-assessment. The study required voluntary participation, and a number of patients telephoned to say that they did not want to take part in the assessment. Some patients had returned to work and did not want to take any more time off, whilst others expressed anxiety about being assessed. One patient had sustained his injury in a fight with a family member, and wanted to forget that the incident had taken place. In such cases, cognitive assessment data was coded as 'missing'. In all cases, an RQ was sent to the patient and in most instances this was returned. In addition to this, several patients were unable to undertake formal neuropsychological assessment because of the severity of their impairments and in a few, the severity of the patient's disability was such that an RQ was deemed inappropriate.

The assessment rate in the SAH patients was comparable to that of the TBI group, and likewise, dropped off over the duration of the study. Reasons for non-assessment were also similar.

Comparison of GOS scores revealed that the outcome of those patients who were not assessed was worse than outcome of those patients who were assessed, in both the TBI and SAH groups. This was largely attributable to the proportion of patients who were unfit for

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<sup>7</sup> Formal assessment of cognitive function in the SAH patient group was carried out using a shorter test battery.

assessment. Therefore the results of the cognitive assessment are an optimistic representation of the degree of impairments suffered.

## **Orientation**

### *Temporal Orientation Test (TOT)*

The TOT revealed some orientation problems in the severe TBI group, but these improved over time. The moderate TBI and SAH groups seemed to be unimpaired, but some patients reported that they were aware of the date and time because of their appointment. This may have resulted in an inflated estimation of the patients' orientation.

## **Language Functions**

Formal assessment of cognitive function in the TBI patients revealed that language problems were relatively frequent with poor performances on both the FAST and BNT.

### *Frenchay Aphasia Screening Test (FAST)*

The FAST revealed that a considerable proportion of patients were experiencing language difficulties, particularly those with severe brain injury. The mean scores at the three assessment times showed an improvement over time, and the proportion of patients with low scores also decreased, suggesting continuing recovery over time. These results suggest that the FAST is sensitive to the language problems of this patient population, and also that it is sensitive to change over time, supporting its use as a suitable screening test for use with the TBI and SAH populations.

### *Boston Naming Test (BNT)*

Other workers have reported that anomia is the most common language disorder in TBI patients (Heilman et al. 1971; Capruso and Levin, 1992) although naming problems are more obvious upon formal assessment using confrontation naming tests such as the BNT (Newcombe, 1982) than in spontaneous speech. These findings are supported by the results of the present study: anomia was both common and persistent following TBI, with the severe group performing significantly more poorly than the moderate group. The results showed improvement over time both in group mean scores, and in the proportion of patients who were performing poorly on the test. Thus the BNT would seem to be sensitive to the detection of word-finding difficulties of these patients, and to change over time.

Although the BNT was not used with SAH patients in the present study, it may be potentially useful for this patient group, considering the similarities between TBI and SAH patients on other tests.

## **Memory Functioning**

Memory problems are widely accepted to be among the most common sequelae of TBI (Brooks, 1972; Lezak, 1979; Capruso and Levin, 1992; Lezak, 1995). The story recall task is one of the best available assessment methods (Newcombe, 1982) and is widely used to detect memory disorders following TBI (Brooks et al. 1986b; McMillan and Glucksman, 1987; Conzen et al. 1992; Kreutzer et al. 1993). Likewise, the complex figure test is another popular assessment tool for this patient population (Brooks, 1972; Newcombe, 1982; Brooks et al. 1986b; McMillan and Glucksman, 1987).

### *Story Recall*

The story recall test revealed problems with verbal memory in some patients in both TBI and SAH groups. However, a comparison of scores over the three assessment sessions is not possible because of the lack of comparability between the parallel forms of this test, as discussed in Chapter 3 Section 3.2, making interpretation of recovery over time very difficult. This is reflected on group mean scores and in the proportion of patients performing poorly on the test at the 12 month assessment. One consistent pattern is that the severe TBI group perform more poorly than the moderate TBI or SAH groups, who perform equivalently, and that memory problems persist in some patients.

### *Complex Figure Test*

Again, the use of parallel forms of the Complex Figure Test introduces problems in the interpretation of change over time. Severely injured TBI patients have difficulty with the recall trial at all three assessments, but the proportion of patients with poor scores is least at 12 months. Of the SAH patients, none have impaired scores at 12 months, although a proportion of the group do at 6 and 24 months. These results are consistent with a difference in difficulty of the parallel versions, with the Taylor figure used at 12 months being easier than the original Rey-Osterrieth figure. A proportion of the moderate TBI group have difficulty with the recall trial at all three assessments, but this is hidden on the mean score analysis.

Another factor which may influence the scores on the recall trial of this particular test is that the recall is carried out without warning. However, at 12 and 24 month assessments some patients remembered that they would be asked to draw the figure from memory, whilst others did not. This is likely to advantage those patients who remember the recall trial in that they may pay more attention to the figure whilst copying it, or may try to use strategies to help them to remember it. This may be a contributory factor to the significant difference

in performance between the moderate and severe TBI patient groups at 12 and 24 months, a difference which failed to reach significance at six months post-injury.

## **Concentration**

### *Trail Making Test (TMT)*

Performances on the TMT showed that the severe TBI group were more severely affected than the moderate group. Both TBI groups showed an impaired performance at six months post-injury, and thereafter an improvement in the group mean scores over the three assessments. Mean scores for the SAH group appear unimpaired but a proportion of patients performed poorly, although this decreased over time. This would confirm other reports that the TMT is sensitive to any brain injury (Lezak, 1995), and also support its use as a sensitive indicator of recovery over time.

One difficulty which arose when using the TMT was that a number of patients reported being 'not good at my letters'. In some cases, the patient's data were excluded because their inability to place letters in correct alphabetical order removed any useful meaning from the test scores.

### *Paced Auditory Serial Addition Task (PASAT)*

At the outset of the study the PASAT (Gronwall and Wrightson, 1974) had been chosen for inclusion in the test battery. It was intended that subjects be asked to try the 4-second presentation rate and, if they performed at a level of 60% or better, then to attempt the 2-second presentation rate. However, it was found that the level of information processing required in order to be able to perform the task was beyond that of many patients. A number of people failed to understand the instructions and so the data collected was invalid, in that it was not a true reflection of their information processing capacity, but confounded by the limits of their comprehension. The task was the most 'difficult' of those included in the battery and many patients attempted it but gave up. Often, once an error was made the subject found it hard to return to the task thus instilling a sense of failure. Because the digits are presented at a uniform rate using a tape some subjects found it very stressful and asked to stop. A very small proportion of the patients could complete this task, and these tended to be people who had made good recoveries, had returned to work, and reported no change in their levels of functioning relative to pre-morbid performance.

The PASAT was first developed for use with patients following minor or mild TBI, who experienced relatively subtle deficits of information processing capacity, although it has been used with patients following severe TBI (Brooks et al. 1989; Ponsford and Kinsella,



1992). The PASAT was sensitive to these subtle problems, but with the patient population described here it was deemed unsuitable in retrospect in that it led to high levels of stress and anxiety, and a lot of missing data.

Other workers report having reservations about the use of the PASAT. Lezak (1995) does not use the PASAT unless it is necessary to demonstrate very subtle deficits of information processing capacity, where the sensitivity of the PASAT renders it the most suitable test. These are likely to be mildly injured patients only.

A recent paper by Ward (1997) also highlights one of the difficulties of using the PASAT. When comparing a group of University students (mean age 25), with a group of older people (mean age 52), matched on IQ as estimated using the NART, he found that the younger subjects showed significantly poorer performance on the PASAT. The reason for this is believed to be that the younger generation is poorer at mental arithmetic and that, despite involving information processing speed, the PASAT is influenced by arithmetic ability.

From the results of the current study the PASAT is not recommended for routine use with severe and moderate TBI patients. Some SAH patients were able to do the PASAT but reported that they found it stressful. These tended to be patients with good grade SAH who had made a good recovery. On this basis, the present findings are in agreement with Lezak, that the PASAT should be used when it is in the patient's interest to demonstrate subtle deficits of information processing capacity, but not routinely.

## **Frontal Lobe Injury**

### *Modified Card Sorting Test (MCST)*

The MCST (Nelson, 1976) has been used to detect frontal lobe deficits in patients following TBI (Levin et al. 1987a), although testing was carried out within 24 hours of scanning of patients with moderate or mild CHI and by 1 month post-injury performance did not differ from a control group. Its usefulness in the present study would appear limited, as both TBI and SAH groups performed within normal limits on average at all time intervals post-injury. Only a very small proportion of the sample scored poorly on the test. A potential problem in using the MCST is that it is widely used with the brain-injured population, and some patients were familiar with the test when presented with it at six months post injury. Some people appeared to have 'learnt' the three methods of colour, shape and number, by which to sort the cards. It may be that the MCST would give more valuable information if the time taken to sort the cards were taken into consideration. When asked to change the way the cards were sorted, some patients sat for a considerable period of time trying to work out an

alternative method of sorting. This led to them making no errors, but taking an inordinate length of time in attempting to solve the problem.

### **Additional Tests**

#### *Digit Span*

The Digit Span was not used with the SAH group in the present study. Mean scores in both TBI groups showed near normal performances. This could be the result of the use of a combined score comprising digit span forward and digit span backward. Digit Span Backward is reported to be sensitive to neurological damage (Kapur, 1988), but this could be masked by the use of a total score. A proportion of the severe TBI group performed poorly, but this is masked by the use of the group mean score.

Although individual patients may have specific problems with this sub-test, a majority of patients have been able to perform them at or above the average level. These results are in agreement with those of Kreutzer et al. (1993), and would seem to confirm that the Digit Span sub-test of the WAIS-R may be of limited use in group studies of TBI.

#### *Digit Symbol*

The Digit Symbol sub-test of the WAIS-R revealed poor performances by both TBI groups, with the severe group significantly worse than the moderate group. Both groups showed an improvement in mean score over time, and there was a decrease in the proportion of severe TBI patients with low scores. This supports other workers' recommendation of the use of the Digit Symbol as a sensitive measure of impairment in the TBI population (Mandleberg and Brooks, 1975; Correll et al. 1993; Lezak, 1995). Unfortunately, the Digit Symbol was not used with the SAH group, although the results with the TBI groups suggest that it may have some use as an indicator of the degree of impairment following SAH.

#### *Block Design*

The Block Design test was also omitted from assessment of the SAH group. It revealed a between-groups difference in the TBI patients, with the severe TBI group performing at a lower level than the moderate group. However, both groups scored near or above normal over the three assessment sessions, and both showed an increase in group mean score over time. Looking at the proportion of patients who performed poorly, the severe group showed an improvement over time, but none of the moderately injured patients had low scores at any assessment time.

Similar findings have been reported by Correll et al. (1993), investigating the performance of a group of 50 CHI patients on the various sub-tests of the WAIS during the *acute* stages of injury. The CHI patients achieved a block design scaled score of approximately 9.5, which was elevated relative to other sub-test scores, and was not significantly different from the performance of a group of psychiatric control patients. However, patients with moderate or severe CHI performed at a lower level than those with minor CHI.

## SUMMARY

The results show that some tests appear to be more sensitive to the effects of brain injury and to change over time than others, and may help in the formulation of an appropriate assessment battery for use with this patient population. Some tests, although sensitive, may prove difficult for some patients for reasons other than cognitive impairment.

The results also demonstrate the value of looking at the proportion of patients with low scores, as individuals' difficulties can be masked by group mean scores. This has illustrated that patients with moderate injury do suffer identifiable cognitive impairment, although the proportion of patients affected in this group is less than that in the severely injured group. The SAH patients showed an improvement over time, to such an extent that at 24 months performance was at a level consistent with that expected in the normal population. However, this accounted for performance in those who were able to be assessed, and it should be remembered that some patients (14%) were adjudged to be 'unfit for assessment' two years post-haemorrhage. These findings would support a full investigation of cognitive recovery following SAH, especially in patients with more severe grades of injury.

## **Cognitive Outcome following TBI : moderate versus severe injury**

Macciocchi et al. (1993), in a review of disability after head injury, reported that moderate to severe head injury is typically followed by a

'persistent and extensive neuropsychological, psychiatric and occupational impairment' (p773).

Nevertheless, very few studies have compared outcome, or degree of cognitive impairment, between groups of patients with moderate or severe TBI. Kreutzer et al. (1993) investigated the neuropsychological characteristics of patients following TBI with a range of severity of GCS 3 - 12, corresponding to severe and moderate injury. However, they did not group patients on the basis of severity of injury, but compared assessment at baseline and 1 year post-injury. Baseline assessment was 'typically completed within 10 days of hospital discharge' (p50) with a mean of approximately 49 days post-injury (range from 2 to 260

days post-injury). On all tests, the proportion of patients scoring more than 1 standard deviation below the mean fell between baseline and 1 year follow-up. This is a similar finding to that reported for the severe TBI group in the present study, although the pattern for the moderately injured group is not so clear. It is possible that those moderately injured patients who returned for assessment were those with the greatest degree of impairment, and so the proportion of patients scoring poorly becomes an over-representation at 12 and 24 months.

Dikmen et al. have published reports of outcome following moderate to severe head injury (Dikmen et al. 1990; Dikmen et al. 1993). However, there are a number of problems when considering their reports in comparison with the current study. Again, no distinction is made between patients with moderate and severe injury; their reports refer to 31 patients with a GCS of 3 to 8 within 24 hours of admission, and/or a PTA of at least 2 weeks duration. This definition of 'moderate to severe' would be interpreted by most workers as indicative of severe TBI. In addition to this, extensive selection criteria were used so that the characteristics of their patient population appear different to those in other reports. For example, 27 of their 31 patients sustained their TBI in a motor vehicle accident, 2 fell and 2 were hit by falling objects.

One of the few studies which has compared outcome between patient groups following moderate or severe TBI is that of Correll et al. (1993). They report performance on the WAIS (Wechsler, 1955) in mild, moderate and severely injured CHI patients, during the acute recovery stage. They found no difference between the performances of the moderate and severely injured groups, but both performed at a significantly lower level than those with mild injury, who performed at a level equivalent to a control group of hospitalised psychiatric patients. However, there are one or two difficulties in drawing conclusions from their study. The subjects comprised a group of patients consecutively referred for neuropsychological assessment, aged between 21 and 35 years, and who were able to complete the assessment. This would suggest that their patient sample was biased. The fact that testing took place during the patients' hospitalisation soon after injury would suggest that completion of the assessment would be impossible for some patients, particularly those who were more severely injured. As completion of the entire WAIS was a criterion for entry into the study, this would again suggest a bias away from those who were severely cognitively impaired.

Another study of moderate and severely injured patients is described by Anderson et al. (1994). They report a study of 6 month follow-up of a group of 35 severe TBI patients and a group of 26 moderate TBI patients. They found no difference in either GOS outcome, or performance on formal cognitive assessment, between groups. However, this is likely to be due to a crucial methodological point: the moderately injured patients of Anderson et al. had been selected for ITU monitoring and were not entirely typical of all moderately injured patients passing through the neurosurgical unit. Thus they were likely to be the more severely injured moderate TBI patients. No such bias existed in the present study. Comparison of 6 month GOS scores in Anderson's study and the present study reveals a very similar distribution of outcome in the two severe TBI patient groups. However, patients in the moderate TBI group in Anderson's study have much higher levels of disability than the moderate group in the current study.

Thus no directly comparable study exists in the literature. The findings from the current study appear to be in agreement with those of Rimel et al. (1982) in suggesting that people with a moderate TBI have a degree of morbidity intermediate between those with severe and those with minor TBI. This is indicated by the performances of the moderate TBI patients on formal assessment: they perform at a higher level than the severe TBI groups, but lower than expected on the basis of the normative data available.

### **Cognitive Outcome following SAH**

Published reports of cognitive outcome following SAH describe mixed results, although there are difficulties in making comparisons between studies because of selection criteria or lack of information. McKenna et al. (1989b) investigated outcome at discharge, three months and one year after haemorrhage in a group of 100 SAH patients, 17 of whom were excluded during the course of the study. In the 70 patients without neurological deficit, the authors found that they were functioning at a reduced level on cognitive tests at discharge, but by three months this had improved to a level at or near their estimated premorbid state. They concluded that:

“the typical pattern in a straightforward case was a gentle convalescence and then the patient returning to a normal lifestyle by three months” (p487).

The remaining 13 patients with neurological deficits were considered ‘exceptions to the rule’ and their outcome was not discussed further.

In another paper detailing cognitive outcome of the same patient group, McKenna et al. (1989a) conclude that:



“More extensive testing of specific subgroups of SAH patients is unlikely to yield results that could seriously challenge the main conclusion of this study, namely, that patients recovering from an uncomplicated history of SAH should expect no permanent disruption to their cognitive or emotional life ” (p366).

One of the problems in interpreting the study of McKenna et al. is that neither paper reports details of the grade of SAH in their patient group, although 87% of patients were surgically treated, compared with 75% of patients in the present study.

However, other studies have reported different findings. Hütter and Gilsbach (1993) found that patients who were classified as having made a good recovery on the GOS at six months post-haemorrhage often had underlying neuropsychological deficits: 53% of their sample had impaired short term memory, with 21% experiencing impaired long term memory.

Another study (Van Harskamp et al. unpublished data, cited in Vermeulen et al. 1992 ) found that memory and concentration impairments were experienced by many of their patients more than one year post-haemorrhage, and these occurred no more frequently in patients with complications than without, or positive rather than negative angiography. The precise methods by which Van Harskamp et al. reached their conclusion are unclear, but such results would suggest that McKenna’s claims are not justified.

The results of the present study are in keeping with reports in the literature. As in McKenna’s study, the results of formal cognitive assessment suggested that patients tend to recover well or remain very severely disabled. However, the patients in McKenna’s study apparently recovered more quickly than those reported here, although this may be a result of a less severe grade of SAH. In agreement with Hütter and Gilsbach (1993), a proportion of patients in the present study showed signs of neuropsychological disturbance at six months post-haemorrhage. Consideration of the RQ data reveals a different picture.

## 8.5 Relative’s Questionnaire

The RQ was originally devised as the basis of a semi-structured interview of relatives of patients with TBI, and since then has also been used as a questionnaire, giving information about many ways in which the patient may have been affected by their TBI. The benefits of gathering information from a relative or friend of SAH patients was described by McKenna et al. (1989b), who commented that the most useful source of information concerning outcome was a semi-structured interview with a close friend or relative of the patient.

Any questionnaire measure is open to a certain degree of error and response bias which may distort the information provided, and reported changes may not necessarily reflect actual changes. The respondent, or primary carer in this instance, may provide inaccurate reports for a variety of reasons. They may tend to under-report problems in an attempt to indicate that they are coping, or to show the patient in the best possible light. Alternatively, if they are stressed or finding it difficult to cope, there may be a tendency to over-report difficulties. The respondent's understanding or interpretation of the questions may also differ from those intended.

### **RELATIVE'S QUESTIONNAIRE: COMPARISON BETWEEN TBI AND SAH**

By using the RQ with both TBI and SAH groups, it was hoped that useful comparisons concerning the pattern of problems between the two groups would be possible. The use of the RQ with SAH patients has not been previously reported in the literature although a group of SAH patients was included in the reliability study (Hellowell and Signorini, 1997b). The results reveal that problems in all areas of function are reported by the relatives of both the TBI and SAH patients. When looking at the most commonly reported individual symptoms following TBI or SAH, there is a considerable degree of similarity. Tiredness and memory problems are frequently reported by relatives in all groups at each of the three assessment times.

The proportion of SAH patients affected was lower than that of the moderate and severe TBI groups for most areas of function, although the severity of injury of the SAH patients was believed to be less than the severity of injury of the TBI groups, which may account for this result. Nevertheless, the range of number of problems was similar in the SAH and TBI groups, suggesting that some patients were severely affected by their SAH, and some TBI patients recovered well.

### **COMPARISON BETWEEN COGNITIVE ASSESSMENT AND RELATIVES' REPORTS**

#### *Memory*

Memory problems have been reported by relatives in between 50 and 60% of cases, throughout the duration of the study. In contrast to this, tests of memory revealed a much smaller proportion of patients performing at a level of 1 standard deviation or more below the mean. Scores on formal assessment have improved over time, suggesting an improvement in patients' memory function. However, the impact of practice effects is not known, and the use of parallel versions of the two memory tests added confounding variability to the data, making interpretation of the results even more difficult. The

comparison between the RQ and cognitive data can only be made at a crude level because of the number of factors which may be contributing to this difference between formal assessment and reports of observed behaviour. Some patients may be forgetting things more often than prior to their brain injury, and this is reported by their relatives on the RQ, despite their performance on formal assessment being within normal limits. Another obvious factor is that those patients who completed formal assessment are a subgroup of those on whom RQ data are available. The outcome of those patients who undertook cognitive assessment was shown to be better than the outcome of those who did not, and so the results of the cognitive assessment are known to be an overestimate of degree of recovery. However, this was particularly so in the severe TBI group, and would not account for the severity and frequency of problems reported by relatives of the moderate TBI group.

Another factor may be that the ways in which memory are affected by the head injury are not being adequately investigated by formal assessment. To quote from Dikmen et al. (1987):

“impairment in memory depends on the type of task used, time from injury to testing, and on the severity of head injury (that is, degree of impaired consciousness).” (p1613)

Also, the main memory tests used here focus on just one of the various facets of memory, namely ability to retain new information over a relatively short period of time.

The relatives’ reports of the ways in which memory was affected are shown for all three patient groups in Table 8.1 below.

**Table 8.1      Types of memory failure reported by relatives (shown as % of each group)**

	6 month			12 month			24 month		
	sev	mod	sah	sev	mod	sah	sev	mod	sah
Forget names	37	20	28	26	24	33	24	26	19
Mislay things	59	43	33	59	43	30	44	48	33
Not recognise faces and/or places	27	13	8	27	12	12	25	7	19
Forget things they’ve been told	65	43	47	68	58	36	52	56	46
Forget the day	40	20	14	32	18	12	20	15	19
Get lost if out alone	16	0	6	16	10	3	14	8	8

These results reveal a similar pattern between groups, with the most commonly reported difficulties being forgetting things patients had been told and mislaying things. The least frequently reported problem was getting lost when out alone. However, for a number of patients this particular question was not applicable, because some patients never went out without a carer.

### *Language*

When comparing results of the RQ and formal assessment of language abilities, the opposite pattern is found: a high proportion of patients perform at a lower level than expected on formal assessment, although relatives' reports of language problems are much less frequent. The language category of the RQ contains three questions pertaining to language problems, and the frequencies of relatives' reports is given in Table 8.2 below.

**Table 8.2**      **Types of language problem reported by relatives (shown in % of each group)**

	severe			moderate			SAH		
	6	12	24	6	12	24	6	12	24
Slurred speech / stammer	43	34	36	24	27	15	9	22	15
Word finding	43	42	36	31	39	41	33	36	27
Understanding	39	17	32	7	22	15	6	6	8

The greatest discrepancy is between reports of word-finding difficulties and performance on the Boston Naming Test. Naming problems are known to be most obvious on confrontation naming tests such as the BNT (Newcombe, 1982). This discrepancy in results may partly be explained by the amount of redundancy in everyday conversation: if someone has difficulty in remembering a word it can be relatively easy to overcome this by a process of circumlocution, with the result of being perfectly understood.

### **Relative's Questionnaire and TBI: moderate versus severe injury**

It has long been recognised that patients with TBI, particularly severe brain injury, may underestimate the extent of their problems when compared with reports of relatives or carers (Wilson, 1991; Macciocchi et al. 1993). The RQ was used to counteract such problems in an attempt to enable a fair comparison between those with moderate and severe injury.

The data revealed changes resulting from the brain injury throughout all areas of function. However, the most remarkable feature of the RQ data was the similarity between groups, a

finding previously reported by Anderson et al. (1994). The only significant difference between groups throughout the duration of the current study was in the category of 'dependency' at 12 months post-injury. However, there are a number of things to consider when looking at the results of the RQ analysis. First of all, the RQ offered the options 'no change', 'rather worse since injury', or 'much worse since injury' in response to each item. The discrepancy between 'rather worse' and 'much worse' is purely subjective, so the two possible answers were collapsed into one. Thus the analysis investigated only whether the injury had resulted in 'no change' or 'worse since injury', and so in effect was an analysis of the mean number of problems reported by relatives of the moderate and severe patients. However, it may be the case that those with severe injury are experiencing more severe problems than the moderately injured patients, although the nature of the problems, and therefore the mean number of symptoms, may be the same. In order to investigate if this was the case, the data were re-analysed using scores of 0 = no change; 1 = rather worse since injury; and 2 = much worse since injury. Sum scores for different categories were again calculated for each patient. Mann-Whitney U tests were carried out on the data from the TBI patients in order to compare groups at each of the three different assessment times, and are shown below.

**Table 8.3 Mean sum severity of reported symptoms per category of function in TBI groups**

Function	6 months			12 months			24 months		
	sev	mod	p	sev	mod	p	sev	mod	p
Language	1.72	0.71	0.082	1.17	1.03	0.732	1.56	0.78	0.602
Memory	2.35	1.31	0.072	1.82	1.47	0.465	1.57	1.46	0.941
Physical	4.97	3.41	0.123	4.29	2.90	0.218	4.42	3.48	0.334
Emotional	4.45	4.20	0.972	4.75	4.70	0.968	3.71	4.89	0.334
Disturbed Behaviour	2.65	2.14	0.632	3.56	2.64	0.275	2.71	2.80	0.601
Social Behaviour	2.23	1.40	0.155	2.28	1.63	0.170	1.50	1.59	0.769
Subjective Symptoms	5.90	4.59	0.301	5.25	4.63	0.620	4.63	4.96	0.762
Dependency	3.67	2.47	0.113	3.17	2.06	0.020	3.39	2.08	0.367
Total Symptoms	25.3	19.9	0.672	19.6	18.0	0.733	20.8	21.2	0.762

As with the original data analysis of mean number of problems, the only significant difference between groups is in dependency at 12 months post-injury. The scoring system used in the analysis of severity is crude, but results suggest that there is little difference in relatives' reports of the severity of problems between groups. Thus in terms of functional



outcome, there would seem to be little difference between groups based on severity of their initial injury.

### **Relative's Questionnaire and SAH**

There are no previous reports of the RQ being used with SAH patients. Indeed there is a lack of published information on the views of relatives or carers on the functional status of post-haemorrhage patients. The use of the RQ in SAH in this study reveals that relatives report these patients as experiencing problems in all eight areas of function. This suggests that it is a relevant and appropriate tool for use in this brain-injured population, as in TBI.

## **8.6 Mood Disorders**

### **Hospital Anxiety and Depression Scale**

In a review of the literature, Morton and Wehman (1995) found that high levels of anxiety and depression following severe TBI were reported by many authors, and that the presence of one such emotional disturbance was often accompanied by the other. For example, Schoenhuber et al. (1988) report one year follow-up of 103 minor TBI patients, and found that the prevalence of depression was 39% and anxiety 26%.

In the present study this was not the case. When compared with estimates of the prevalence of anxiety and depression in patients in primary care medical practice (Goldberg, 1995), the present results would seem to suggest a slight increase in the prevalence of anxiety following TBI, without any change in level of depression. There was no difference between the moderate and severe TBI groups. The SAH group show no apparent sign of an increased prevalence of anxiety or depression relative to primary care patients.

Van Zomeren and van den Burg (1985) report the prevalence of patients' self-reported symptoms of 'depressed mood' and 'more anxious' as 19% and 18% respectively in their sample of 57 patients two years after severe head injury. Likewise, Levin et al. (1979a) in a report of one year outcome in 24 patients following severe TBI, report the prevalence of anxiety-depression as 25%. The results of the current study are in line with these findings. Nevertheless, it should be remembered that the TBI population differs in age, lifestyle, and other demographic variables from the general population, and the influence of these differences is unclear.

In agreement with Morton and Wehman (1995) there was found to be a strong correlation between levels of anxiety and depression in TBI patients at all three time intervals

( $r = 0.67$ ;  $p < 0.001$ :  $r = 0.71$ ;  $p < 0.001$ :  $r = 0.60$ ;  $p < 0.001$  at 6, 12 and 24 months respectively) and in the SAH group ( $r = 0.71$ ;  $p < 0.001$ :  $r = 0.75$ ;  $p < 0.001$ :  $r = 0.56$ ;  $p = 0.013$  at 6, 12 and 24 months respectively).

**COMPARISON BETWEEN HAD AND RQ REPORTS**

Morton and Wehman (1995) point out that many studies of anxiety and depression following TBI rely on the reports of relatives or significant others. In order to investigate this further, the proportion of relatives who reported change in the patient’s level of anxiety and depression was calculated. Details are given in Tables 8.4 and 8.5 below.

**Table 8.4      Changes in anxiety as reported by relatives (given as % of each group)**  
**0 = no change; 1 = rather worse; 2 = much worse**

	severe			moderate			SAH		
Tension/anxiety	0	1	2	0	1	2	0	1	2
6 months	36	31	33	33	57	10	64	33	3
12 months	36	39	24	34	53	13	64	33	3
24 months	44	44	12	44	22	33	69	27	4

**Table 8.5      Changes in depression as reported by relatives (given in %)**  
**0 = no change; 1 = rather worse; 2 = much worse**

	severe			moderate			SAH		
Depression	0	1	2	0	1	2	0	1	2
6 months	46	37	17	53	23	23	79	15	6
12 months	57	26	17	39	52	9	82	15	3
24 months	48	32	20	56	22	22	75	21	4

In the TBI and SAH groups, relatives report change in anxiety more frequently than change in depression. These results are in accordance with the results of the HAD, with more patients reported to be experiencing anxiety than depression. However, in both TBI groups, relatives report change in anxiety and depression in over half of the patients. In the SAH group, change in anxiety and depression is reported in about 20 to 35% of patients, with little change over time.

Thus the results would suggest that changes in anxiety and depression may be relatively common, but these changes are of insufficient severity to warrant a diagnosis of clinical anxiety or depression using a tool such as the HAD. This may also account for the apparent

disparity in the literature: methods used to estimate change in anxiety and depression vary, leading to inevitable problems in drawing comparisons between studies.

## 8.7 Head Injury Symptom Checklist

The HISC was used in the present study to enable quantification of the frequency of a range of commonly reported post-concussion symptoms. The use of the HISC with SAH patients has not been previously reported in the literature, but results of the present study would indicate the relevance of such a checklist for use with the SAH population.

### **Head Injury Symptom Checklist: Comparison between TBI and SAH**

Typically, post-concussion symptoms are reported following minor or mild head injury, although some workers have reported their frequency following more severe TBI.

The symptoms reported here reveal a different pattern between groups. At six months post-insult the proportion of SAH patients reporting individual symptoms is roughly similar to the moderate TBI group with the exception of irritability and bad temper, which are reported by relatively few SAH patients. At 12 and 24 months a smaller proportion of SAH patients report cognitive and emotional symptoms than either the moderate or severe TBI groups. This difference between groups may be partly accounted for by the less severe brain injury in the SAH patients, leading to fewer cognitive problems. However, the proportion of SAH patients reporting subjective symptoms such as headaches, fatigue and hypersensitivity to noise or light is roughly equivalent to that of the severe TBI group, and appears to increase over time.

Van Zomerén and van den Burg (1985) reported on patients' residual complaints two years after severe TBI. They found that 84% of their sample of 57 patients had some residual problem whilst the most commonly reported complaint was of being forgetful (54%). In contrast to their findings, the most commonly reported complaint in the current study was that of increased fatigue, reported by 50 to 60% of patients at two years post-injury. However, there are problems with van Zomerén and van den Burg's study. They provide no clear definition of severe TBI, and patients were restricted to those who were admitted to a Department of Neurology, thereby biasing their patient sample.

In the present study, the proportion of severe, moderate and SAH patients with at least one residual complaint at two years post injury was 76%, 90%, and 89% respectively. Although the proportion of severe TBI patients with no complaints was greater than in the other two groups, this may be partly explained by lack of insight in some very severely impaired

patients. The range of number of symptoms was greatest in the severe group, ranging from 0 to 12, as opposed to 0 to 9 in the moderate group and 0 to 8 in the SAH patients. Thus symptoms commonly referred to as comprising post-concussion syndrome would seem to be prevalent following brain injury of a broader definition.

### **Head Injury Symptom Checklist following TBI : moderate versus severe injury**

Although Dikmen et al. (1993) report the use of the HISC at a two year follow-up of patients with moderate to severe TBI, there are difficulties in interpreting their studies, as described earlier. However, they found that some symptoms, such as headaches and fatigue, improved over time whilst others, such as memory difficulties and irritability, remained frequent throughout the two year duration of their study. The results from the severe TBI group in the present study are in accordance with this, although the moderate TBI group show a more generalised improvement than the severely injured patients.

### **Head Injury Symptom Checklist following SAH**

The use of the HISC with the SAH patients shows how prevalent post-concussion symptoms are in this patient group. The repeated use of the HISC revealed an improvement over time in reports of emotional and behavioural symptoms, whilst subjective symptoms such as headaches and fatigue persisted, and in some areas, such as sensitivity to noise and light, deteriorated over time. These results would suggest that the use of such a checklist with SAH patients is warranted.

### **COMPARISON OF HISC AND RQ REPORTS**

A number of workers have documented differences in the reports of relatives and patients concerning changes arising from the brain injury. In some cases, this may be due to lack of insight in some patients (Wilson, 1991; Dikmen et al. 1993). Others have alluded to the fact that the size of discrepancy between the reports of a patient and relative depends on the nature of the problems being described. Some workers have noted a greater agreement between patient and relative in the report of sensory-motor problems, than in report of emotional and behavioural changes (McKinlay and Brooks, 1984). Other studies have suggested that the degree of difference varies according to the severity of injury, with bigger discrepancies in patients who were more severely injured (Brooks, 1991). This is likely to be the result of a combination of factors: patients with less severe injuries are likely to have a greater degree of awareness of their deficits, and are also likely to have fewer deficits for either the patient or relative to report.

### **HISC and RQ reports in TBI: moderate versus severe injury**

In the present study, the results from the HISC would suggest that the moderately injured patients report improvement over time, especially in terms of subjective symptoms such as headaches and dizziness. However, results from the RQ would suggest little or no improvement over time. When drawing such comparisons it is important to remember that the HISC data is derived from fewer patients who have been shown to have a significantly better outcome than the population as whole, whilst the RQ data is much less likely to show such a bias. Nevertheless, in the severe TBI group little change over time is reported either by patients or relatives using the HISC or RQ respectively.

### **HISC and RQ reports in SAH**

Tiredness is the most commonly occurring symptom, being reported by approximately 60% of patients and relatives. Difficulty with remembering things is another frequently observed sequela, although it is reported more commonly by relatives than by patients themselves. This may be due to a lack of insight in some patients.

McKenna et al. (1989a) report that the most common complaint in their study was of increased fatigue, reported by 10% of patients. In the present study, it is also the most common complaint, but is reported by approximately 60% of the patient group throughout the duration of the study. The reason for this discrepancy is not clear, although there are problems with McKenna's study, as described earlier (see Chapter 8; Section 8.4).

One difference which appears between patients' and relatives' reports is in the frequency of emotional and behavioural change. Relatives' reports would suggest that emotional and behavioural problems increase in frequency, whilst patients' reports indicate a decrease in irritability, anxiety and loss of temper. The reason for this difference of opinion is not clear, although it could be partially accounted for a lack of insight and self-appraisal in patients with 'frontal lobe' symptoms, whose behaviour and emotion is more likely to be affected by the injury than patients with less anterior damage.

## **8.8 Summary**

The main aims of this thesis were to examine outcome following TBI or SAH, and in particular, to study cognitive functioning and its recovery over time. Having considered the data collected, it is apparent that information is available from a number of sources: from formal cognitive assessment; from relatives' reports using the RQ; and from patients' own reports using the HISC. However, there are difficulties in making a direct comparison



between the different assessment tools used because of the nature of the data these provide. Although formal cognitive assessment using standardised reliable methods provides a means of quantifying estimated level of impairment, many patients were unable to undertake testing. The RQ and HISC both rely on observational report and are therefore open to bias of various kinds.

The results of the study give a very mixed picture. When comparing outcome of the moderate and severe TBI groups, those with moderate injury have a significantly better outcome, measured on the GOS, than the severely injured. Nevertheless, many remain moderately disabled, and are therefore affected by their injury in a lasting way.

Subarachnoid haemorrhage patients appear to show one of two recovery paths: they either recover relatively well or have a long and complicated course of recovery often accompanied by very severe disability.

As regards the analysis of cognitive assessment, the severe TBI group show signs of impaired memory, concentration and information processing abilities, whilst the moderate TBI group appear affected to a lesser degree. Thus the findings of Rimel et al. (1982) are supported in the present study, and the recommendation is made that further investigation of the moderately injured group is necessary in order to optimise their full potential for recovery.

The majority of the SAH patients who could be assessed cognitively, performed at, or near, a normal level expected on the basis of existing normative data. However, a proportion of SAH patients had such severe impairments and disabilities as precluded such assessment, and further investigation of this subgroup of survivors is warranted using alternative measurement instruments to those employed in this study.

When comparing outcome between the TBI and SAH patients, there are a number of factors, such as the severity of injury, which have confounded the comparison. Nevertheless, the results have shown a similar picture of cognitive problems, post-concussion symptoms and a range of functional difficulties reported by relatives. Further research into the similarities between secondary insults to the brain and their relationship to outcome are recommended.

Overall, the TBI and SAH patient groups showed a trend for improving performances on formal cognitive assessment over the three assessment sessions, suggesting that cognitive function continues to recover for some time post-injury. However, there is no consistent decrease in the frequency of memory or language problems as reported using the RQ. This

may be attributable to the fact that fewer patients underwent formal assessment than completed the RQ, or it may be a reflection that the formal methods of assessment do not adequately encapsulate the ways in which cognitive function is affected in everyday life. The importance of these functional aspects of cognition has been emphasised by others (Ponsford and Kinsella, 1991; McPherson et al. 1997).

Another reason for the discrepancy may be that cognitive tests measure current level of functioning, and although there are methods such as the NART for estimating pre-morbid level, there is a great deal of individual variation in patterns of performance even in non-injured people, making it difficult to know at what point a person's performance is 'impaired'. Conversely, the RQ is more likely to reflect a person's disability in that it requests information about how a person has been affected by their injury.

The relationship between impairment and disability is complex and controversial, and it is likely that there are many contributory factors which affect an individual's ability to adapt to and cope with changes arising from a brain injury. At best, tests of cognitive impairment are indirect markers that reflect functional outcome rather than being, in themselves, functional outcome measures (Diller and Ben-Yishay, 1987). The RQ, on the other hand, is more likely to reflect a person's disability in that it requests information about observed function in everyday life. The GOS, while also regarded as a measure of disability, provides information of a global character with inherent lack of sensitivity or detail of the nature of disability. In the present study no attempt has been made to address the concept of handicap other than in superficial terms (World Health Organization, 1980).

Assessment of level of cognitive functioning remains a necessary pre-requisite for planning any intervention to assist people and their families to recover from, and adjust to, the consequences of brain injury. However, there is a need to supplement such information with measures of everyday function in the social context of the individual with brain injury. It is clear that the majority of people in the three populations studied (moderate and severe TBI, and SAH) have continuing difficulties and ongoing needs for at least two years post-injury. The extent to which these difficulties and needs persist beyond this time period remains to be established.

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## Appendix A

Consent Form

Relative's Questionnaire

GP Letter

GOS Definitions

### Head Injury Outcome Study

We are currently undertaking a major study on head injury. Part of this study is to look at whether such an injury affects your behaviour and physical fitness and to assess the length of time it takes to recover.

We will assess your memory and concentration with a short set of tests. These are not at all painful or harmful and will last for about an hour to an hour and a half. In addition we would like a close friend or relative to complete a questionnaire giving us details of how you are getting on at home.

We would like to see you again in 6 months time and in 18 months time.

Your decision to take part is voluntary and you may withdraw from the study at any time. If you do withdraw it will not affect any treatment you are receiving from this hospital.

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Patient Consent Form

NAME \_\_\_\_\_

ADDRESS \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

I have read the above and agree to take part in this study. I am aware that I can withdraw from the study at any time and that this will not affect my treatment in hospital.

SIGNATURE \_\_\_\_\_

DATE \_\_\_\_\_

# QUESTIONNAIRE FOR RELATIVES

As well as interviewing and assessing the person who was injured, we have found it helpful to ask a relative or close friend how the injured person is progressing. This helps us to make sure that we don't miss symptoms or changes resulting from the injury.

It would therefore be helpful if you would fill in this questionnaire.

NAME OF INJURED PERSON .....

TODAY'S DATE .....

YOUR OWN NAME .....

HOW ARE YOU RELATED TO THE INJURED PERSON? .....

WHO IS THE MAIN PERSON WHO LOOKS AFTER THE PERSON WHO WAS INJURED? .....

The questions which follow are about the injured person's health over the last few weeks, compared with how they were before the injury.

**AS A RESULT OF THE HEAD INJURY, DOES THE INJURED PERSON SUFFER PROBLEMS WITH:** (Circle which answer applies)

6.	<b>Eyesight</b>	no change	rather worse since injury	much worse since injury
7.	<b>Hearing</b>	no change	rather worse since injury	much worse since injury
8.	<b>Sense of taste</b>	no change	rather worse since injury	much worse since injury
9.	<b>Sense of smell</b>	no change	rather worse since injury	much worse since injury
10.	<b>Balance</b>	no change	rather worse since injury	much worse since injury

(Please circle one answer to each question)

11.	<b>Dizzy spells</b>	no change	rather worse since injury	much worse since injury
12.	<b>Headaches</b>	no change	rather worse since injury	much worse since injury
13.	<b>Tiredness</b>	no change	rather worse since injury	much worse since injury
14.	<b>Difficulty sleeping or disturbed sleep</b>	no change	rather worse since injury	much worse since injury
15.	<b>Slowness</b>	no change	rather worse since injury	much worse since injury
16.	<b>Tension or anxiety</b>	no change	rather worse since injury	much worse since injury
17.	<b>Impatience</b>	no change	rather worse since injury	much worse since injury
18.	<b>Finds noise distressing</b>	no change	rather worse since injury	much worse since injury
19.	<b>Irritability</b>	no change	rather worse since injury	much worse since injury
20.	<b>Outbursts of temper</b>	no change	rather worse since injury	much worse since injury
21.	<b>Outbursts of violence</b>	no change	rather worse since injury	much worse since injury
22.	<b>Difficulty speaking (slurred speech or stammer)</b>	no change	rather worse since injury	much worse since injury
23.	<b>Difficulty finding the right word</b>	no change	rather worse since injury	much worse since injury
24.	<b>Difficulty under- standing what words mean</b>	no change	rather worse since injury	much worse since injury



25.	<b>Concentration</b>	no change	rather worse since injury	much worse since injury
26.	<b>Depression</b>	no change	rather worse since injury	much worse since injury
27.	<b>Childishness</b>	no change	rather worse since injury	much worse since injury
28.	<b>Sudden changes in mood</b>	no change	rather worse since injury	much worse since injury

No	Yes
----	-----

No                                      To some extent                                      Very much so

No different                  Rather worse                  Much worse

32a	Do they forget the names of acquaintances?	Yes	No
32b	Do they mislay things?	Yes	No
32c	Do they fail to recognise faces or places?	Yes	No
32d	Do they forget things which you tell them?	Yes	No
32e	Do they forget what day it is?	Yes	No
32f	Do they get lost if they go out alone?	Yes	No

None Occasional Regular

No	Yes
----	-----

35. As a result of the injury, is the patient disabled to the extent that stick, crutches, wheelchair etc. are needed to get about by himself/herself?

Please tick:

- ☐ Fully independent, that is, no aids and no difficulty getting about
- ☐ Gets about without aids but with some difficulty
- ☐ Needs a stick/crutches
- ☐ Confined to wheelchair, can move self in it
- ☐ Confined to wheelchair, needs pushing
- ☐ Confined to bed

36. Has the patient's sex life changed since the injury?

Not adversely affected                      Adversely affected                      Don't know

37. Is the patient independent in self care (washing, dressing, toileting)?

No change due to injury                      Needs more help                      Needs a lot more help

38. Does the patient need supervision outdoors?

No change due to injury                      Needs more help                      Needs a lot more help

39. Does the patient need supervision indoors?

No change due to injury                      Needs more help                      Needs a lot more help

40. Is the patient attending any outpatient clinics?

Yes    No

If "yes" please specify .....

41. What is the patient's NORMAL employment?

.....

42. Just before the injury, what was the patient's work status?

Working full-time                      Working part-time                      Housewife                      Student  
Retired                      Unemployed                      Unfit for work                      School child

43. **Please describe briefly the patient's PRESENT occupation (if any)**  
.....
44. **At the present time, what is the patient's work status?**  
Working full-time      Working part-time      Housewife      Student  
Retired      Unemployed      Unfit for work      School child
45. **Do you think the patient's future employment prospects have been affected by the injury?**  
Not affected      Affected to some extent      Very much worse
46. **Has the patient's leisure and social life changed since the injury?**  
Little or no change      Rather worse since injury      Much worse since injury
47. **Who was to blame for the injury?**  
Patient's own fault \_\_\_\_\_ Another person was to blame \_\_\_\_\_  
Not known \_\_\_\_\_ Other (describe) \_\_\_\_\_
48. **Has there been/will there be an action for compensation?**  
Yes \_\_\_\_\_ No \_\_\_\_\_
49. **Is this settled?**  
Yes \_\_\_\_\_ No \_\_\_\_\_
50. **How much strain have you yourself been under as a result of the injury?**  
Place a tick somewhere from 0 = no strain to 10 = severe strain  
0 \_\_\_\_\_ 1 \_\_\_\_\_ 2 \_\_\_\_\_ 3 \_\_\_\_\_ 4 \_\_\_\_\_ 5 \_\_\_\_\_ 6 \_\_\_\_\_ 7 \_\_\_\_\_ 8 \_\_\_\_\_ 9 \_\_\_\_\_ 10  
No strain strain \_\_\_\_\_ Severe
51. **Has the patient become less sociable since the injury?**  
No change      A bit less      Much less
52. **Has the patient been more outgoing or friendly since the injury?**  
No change      A bit more      Much more

53. **Has the patient been less tactful or well-mannered since the injury?**
- |           |            |           |
|-----------|------------|-----------|
| No change | A bit less | Much less |
|-----------|------------|-----------|
54. **Has the patient's behaviour changed for the worse since the injury?**
- |           |             |            |
|-----------|-------------|------------|
| No change | A bit worse | Much worse |
|-----------|-------------|------------|
55. **Has the patient been looking after him/herself - keeping clean and tidy?**
- |           |           |           |
|-----------|-----------|-----------|
| No change | Less care | Much less |
|-----------|-----------|-----------|
56. **Compared to before the injury, does the patient take an active part in household tasks?**
- |           |      |           |
|-----------|------|-----------|
| No change | Less | Much less |
|-----------|------|-----------|
57. **Does the patient play the same part in making decisions as he/she did before the injury?**
- |           |            |           |
|-----------|------------|-----------|
| No change | A bit less | Much less |
|-----------|------------|-----------|
58. **Does the patient chat about everyday things (news, local events) and take an interest in what you are doing?**
- |           |            |           |
|-----------|------------|-----------|
| No change | A bit less | Much less |
|-----------|------------|-----------|
59. **Have you been able to discuss problems and worries with the patient since the injury?**
- |           |            |           |
|-----------|------------|-----------|
| No change | A bit less | Much less |
|-----------|------------|-----------|
60. **Is the patient as warm and affectionate towards you since the injury?**
- |           |            |           |
|-----------|------------|-----------|
| No change | A bit less | Much less |
|-----------|------------|-----------|
- If applicable:
61. **Compared to before the injury, has the patient been as interested in your sexual relationship and your responses and enjoyment?**
- |           |            |           |
|-----------|------------|-----------|
| No change | A bit less | Much less |
|-----------|------------|-----------|
62. **Has the patient been taking the same interest in the children as before the injury?**
- |           |            |           |
|-----------|------------|-----------|
| No change | A bit less | Much less |
|-----------|------------|-----------|

Date

Dr  
Address

Dear Dr

RE: Patient Name \_\_\_\_\_ Patient Address \_\_\_\_\_ dob \_\_\_\_\_.

We are currently undertaking a major study on head injury and it would be most helpful to have an estimate of any residual disability in the above patient at the present time.

I would be most grateful if you would tick the appropriate outcome category for this patient and return it to me. Details of the criteria for the different outcome categories can be found overleaf. It would also be very helpful to know if the patient has had any epileptic seizures since discharge from hospital.

Also, it would be useful to know if we have the correct address for the patient at the present time.

Please tick:

DEAD

PERSISTENT VEGETATIVE STATE

SEVERE DISABILITY

MODERATE DISABILITY

GOOD RECOVERY.

Thank you very much for your help.  
Yours sincerely

Deborah J. Hellawell  
Research Associate



## Glasgow Outcome Score Categories

GOS 1      Dead

GOS 2      Persistent Vegetative State

GOS 3      **Severe Disability** - Conscious and dependent requiring the help of another person at some time during every 24 hours. Disability may be mental, physical or both.

GOS 4      **Moderate Disability** - Independent, i.e. can dress, make a meal, travel on public transport. Some patients may work but at a reduced level.

GOS 5      **Good Recovery** - Potentially able to return to work (although may be unemployed). May have some personality change, anosmia, mild dysphasia, trivial residual hemiparesis or cranial nerve palsy.

## Appendix B

Publications arising from this Thesis

## Publications

Hellawell,D.J., Anderson,S.I., Jones,P.A., Taylor,R. and Miller,J.D. (1994). Neuropsychological outcome following severe and moderate head injury: work in progress. *Proceedings of the British Psychological Society*, **2**, 57 [Abstract].

Hellawell, D.J. and Signorini, D.F. (1997) The Edinburgh Extended Glasgow Outcome Scale: A Pilot Study. *Journal of Neurotrauma*, **14**, 275 [Abstract].

Hellawell, D.J., Taylor,R., Pentland, B. and Miller J.D. (1997) Twelve month outcome of patients following moderate or severe head injury. *Journal of Neurotrauma*, **14**, 275 [Abstract]

Hellawell, D.J. and Signorini, D.F. (1997) The Edinburgh Extended Glasgow Outcome Scale (EEGOS): Rationale and pilot studies. *International Journal of Rehabilitation Research* (in press).

Hellawell, D.J. and Signorini, D.F. (1997) Reliability and validity of the Relative's Questionnaire. In: *Advances in Neurotrauma: From Research to Community Living*. pp. 115 [Abstract]. Sevilla: Editorial Kronos

Hellawell, D.J., Signorini, D.F. and Pentland, B. (submitted) Simple assessment of outcome after acute brain injury using the Glasgow Outcome Scale.

## Appendix C

Deborah J. Hellowell<sup>1</sup> and David F. Signorini<sup>2</sup> (1997)

The Edinburgh Extended Glasgow Outcome Scale (EEGOS):  
Rationale and pilot studies.

*International Journal of Rehabilitation Research* **20** 345-354.

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## Abstract

The Glasgow Outcome Scale (GOS) is the most widely used outcome measure in head injury research. However, it is a global and relatively insensitive measure, precluding any description of the types of impairments which leads to the disability.

The Edinburgh Extended Glasgow Outcome Scale (EEGOS) was devised as a new outcome measure which retains the advantages of the existing GOS but allows comparison of patterns of recovery in different areas of function; behavioural, cognitive and physical. This report describes pilot studies of the EEGOS used retrospectively, and in 'live' face-to-face interviews. The results show raw percentage agreements of 45%, 60% and 70% in the retrospective study, and 83%, 78% and 83% in the 'live' study. These results demonstrate that the inter-rater reliability of the EEGOS is comparable to that of the GOS applied in similar situations.

## Introduction

The Glasgow Outcome Scale (GOS) (Jennett and Bond, 1975) was devised as a simple practical scale to enable evaluation of outcome in populations of head injured patients. In order to be reliable when used by different observers, it had reduced the complex issue of outcome to five well-defined outcome categories, and was recommended for worldwide use to enable comparisons between different centres (Langfitt, 1978). It is now recognised as the most commonly used head injury outcome measure (Wade, 1992) and, because of its inherent simplicity and reliability, it continues to be recommended for use in large multicentre trials (Clifton et al. 1992).

However, the main criticism of the GOS is that the five categories of death, persistent vegetative state, severe disability, moderate disability and good recovery, make it insensitive in recording change during the recovery process. Ratings of different abilities are collapsed into a single score, and the individual's GOS score is allocated according to their greatest disability, irrespective of its nature. Thus, for example, two patients graded GOS 3 (severe disability) can differ enormously in terms of their functional status and degree of independence/dependence on others.

Several attempts have been made to address these limitations. The originators of the GOS attempted a modification by dividing each outcome category for conscious survivors (severe disability, moderate disability and good recovery) into two, resulting in an eight point scale (Jennett et al. 1981). However, reliability studies were disappointing. The Functional Scale



of Recovery from Severe Head Trauma (Smith et al. 1979) was also developed from the original GOS but involved expansion into a 10 point scale. The authors provided no data concerning the applicability of the scale and it was not widely adopted.

Other workers have departed from the GOS in attempts to develop a broader scale of head injury outcome, which provides more detailed information and is more sensitive to change. One of the most successful of these is the Disability Rating Scale (DRS) (Rappaport et al. 1982) for severe head trauma. This is a 30 point scale comprising ratings on eight items which divide into four categories. It is more sensitive than the GOS in enabling the detection and identification of changes during recovery (Hall and Cope, 1985). The authors report that it is easily learned, quick to use, reliable and valid. Many other measures have been developed and recommended but often they are cumbersome and time-consuming to use, or require special training. None, including the DRS, have been as widely adopted as the GOS which can be used reliably on the basis of case records, or by telephone interview.

We describe an attempt to expand the GOS while retaining its inherent advantages, the Edinburgh Extended Glasgow Outcome Scale (EEGOS), which has been tested for inter-rater reliability on the basis of retrospective and prospective data.

### **The Edinburgh Extended Glasgow Outcome Scale (EEGOS)**

The EEGOS has been developed from the original GOS, but is intended for use with conscious survivors of brain damage due to different causes. It uses the same scoring system for level of recovery (3 = severe disability; 4 = moderate disability; 5 = good recovery) but requires scores for three different types of functioning:

Behavioural/Emotional

Cognitive

Physical

Each patient is assigned a score on each type of functioning, according to the criteria set out by the GOS:

**3** severe disability - dependent upon the help of another person at some time during every 24 hours.

**4** moderate disability - independent but disabled

**5** good recovery - but may be some minor changes.

In order to make the EEGOS reliable, strict criteria need to be set as to which specific functions fall into which category.

**Behavioural/Emotional (BE)** This is designed to cover social behaviour; emotional behaviour; family relationships; personality change; appropriate behaviour; disinhibition; irritability; temper; lack of insight, control, motivation, or spontaneity; loss of emotion; mood swings; anxiety; depression; slowness.

**Cognitive (C)** This addresses the principal areas of cognitive functioning. Specifically, it should take into account functions such as:- orientation; memory; concentration; language (such as word finding abilities, comprehension, expression); visuo-spatial skills; planning; sequencing.

**Physical (P)** This covers physical problems which are a result of brain injury and not caused by associated problems such as orthopaedic injuries. Specific types of disability included in this scale include:- fatigue; hemiplegia; ataxia; diplopia; dysarthria; dysphagia; disruption of vision, smell, or hearing; dizziness; epilepsy.

The EEGOS retains the advantages of the original GOS in that there are strict criteria for determining the patient's level of disability, and a limited number of outcome categories, but attempts to overcome the insensitivity of the GOS by enabling discrimination between types of function and degree of impairment in each one. It gives a possible 27 different outcomes in conscious survivors, from three levels of disability for three different types of function.

A retrospective study was carried out using written information from patient assessments to determine if the scale merits further investigation. One of the intentions, in developing an extended version of the GOS, was that it should be able to be used by clinicians when reviewing patients at outpatient clinics. For this reason a second study was run, involving 'live' ratings of patients.

## Method

### *Retrospective Ratings*

The EEGOS was used by three raters to assess outcome on two groups of ten patients. The raters comprised a nurse (KM), a physiotherapist (PJ) and a psychologist (SA). The scale is intended to be used by workers of all disciplines and it was considered important to include raters from a variety of professional backgrounds.

The first group of ten patients were consecutive admissions to a regional neurosurgical unit with a diagnosis of spontaneous subarachnoid haemorrhage and the second, a group of ten consecutive admissions to the same unit following moderate or severe traumatic brain injury (TBI). Six months post ictus or injury each patient was assessed by a psychologist (DH) on a range of traditional neuropsychological tests, and information from a relative or close friend of the patient was gathered. The neuropsychological tests used were: Temporal Orientation Test (Benton et al. 1983), Frenchay Aphasia Screening Test (Enderby et al. 1987), Paced Auditory Serial Addition Test (Gronwall and Wrightson, 1974), Trail Making Test (A & B) (Armitage, 1946), WMS-R story (Wechsler, 1987), Rey-Osterrieth figure (Rey, 1941), Hospital Anxiety and Depression Scale (Zigmond and Snaith, 1983), and the National Adult Reading Test (Revised)(Nelson, 1982). Relatives were asked to complete the Relative's Questionnaire (RQ)(Brooks and McKinlay, 1983) about the patient's recent behaviour and abilities.

The results of these were given to each rater in written form, in addition to a brief outline of the patient's background, including age, educational level, cause of accident (if TBI) and other factors which might influence pre-morbid functional status (e.g. alcohol abuse). Some test data were incomplete because the patient either refused, or was unable to complete the full assessment.

The raters were asked to score each patient on each of the three dimensions of the EEGOS : behavioural, cognitive and physical. Each rater was experienced in the use of the GOS scale and had received instructions on the use of the EEGOS.

### *'Live' Ratings*

Eighteen subjects were asked to attend a 24 month post-injury review appointment. All subjects had had either a moderate or severe traumatic brain injury, and were being seen as part of other ongoing research projects, rather than specifically for this study. Each subject was seen by a doctor (SC) and a psychologist (DH) in two individual consecutive appointments on the same day. Each rater's assessment was done independently and an EEGOS score assigned. The results were stored without discussion between raters.

Both raters were experienced in the use of the GOS, and had been given instruction in the use of the EEGOS.

## Results

### *Retrospective Ratings*

The results of the retrospective ratings are presented in Table 1. There was overall agreement amongst the three raters in 45% of cases on the behavioural/emotional scale; 60% of cases on the cognitive scale; and 70% of cases on the physical scale. There was only one instance out of 60 (20 patients on three scales) where raters disagreed by two categories. This difference was in rating on the behavioural scale, which shows the largest discrepancies between raters. Kappa coefficients of agreement (Cohen, 1960) ranged from 0.20 to 0.55 for behavioural ratings, 0.56 to 0.63 for cognitive ratings, and 0.57 to 0.75 for physical ratings. Any interpretation of a kappa statistic is essentially an ad-hoc procedure, and it should be noted that with only 20 patients, the accuracy of the values obtained is not high.

**Table 1** EEGOS scores for 20 patients showing agreement between three independent raters on ‘retrospective’ assessment

	Behavioural			Cognitive			Physical		
	Phy	Psy	Nur	Phy	Psy	Nur	Phy	Psy	Nur
Subject 1	4	4	3	3	3	3	4	4	4
Subject 2	5	5	5	4	4	3	5	5	5
Subject 3	5	5	5	3	3	3	3	3	3
Subject 4	4	4	3	4	4	3	4	4	4
Subject 5	5	5	5	5	4	4	5	5	5
Subject 6	4	5	3	4	3	3	3	3	3
Subject 7	4	5	5	4	4	3	4	5	4
Subject 8	5	5	4	5	5	5	5	5	5
Subject 9	4	4	4	3	4	3	4	4	3
Subject 10	5	5	5	5	5	5	5	5	5
Subject 11	4	5	4	4	4	4	5	4	4
Subject 12	5	5	5	4	5	4	5	4	4
Subject 13	5	5	4	4	4	4	5	5	5
Subject 14	5	5	5	5	5	5	5	5	5
Subject 15	4	5	5	3	3	3	4	4	3
Subject 16	5	5	4	4	4	4	5	4	4
Subject 17	5	5	5	5	5	5	5	5	5
Subject 18	5	5	5	5	5	5	5	5	5
Subject 19	4	4	4	5	5	5	5	5	5
Subject 20	5	5	4	4	5	5	5	5	5

Phy = physiotherapist (PJ)  
Nur = nurse (KM)  
Psy = psychologist (SA)

Live Ratings

The results of the live ratings are shown in Table 2

**Table 2** EEGOS scores for 18 patients showing agreement between two independent raters on ‘live’ assessment

	Behavioural		Cognitive		Physical	
	Doc	Psy	Doc	Psy	Doc	Psy
Subject 1	5	5	4	5	5	5
Subject 2	4	4	4	4	5	5
Subject 3	4	4	4	4	5	4
Subject 4	4	4	5	4	4	4
Subject 5	5	5	5	5	5	5
Subject 6	4	4	5	5	5	5
Subject 7	5	5	5	5	5	5
Subject 8	4	4	4	3	4	4
Subject 9	4	4	4	4	4	4
Subject 10	5	4	5	5	5	5
Subject 11	4	4	4	3	3	4
Subject 12	4	4	4	4	3	4
Subject 13	4	4	4	4	5	5
Subject 14	4	5	3	3	3	3
Subject 15	4	4	4	4	4	4
Subject 16	4	5	4	4	3	3
Subject 17	5	5	5	5	5	5
Subject 18	4	4	5	5	5	5

Doc = doctor (SC)

Psy = psychologist (DH)

In this instance, there were no cases where ratings differed by more than a single category. That is, no patient was ever characterised as severely disabled by one rater but classed as



having a good recovery by the other. The raw percentage agreement for the behavioural, cognitive and physical dimensions was 83%, 78% and 83%, with kappa coefficients of 0.61, 0.62 and 0.73 respectively. These values would be unchanged if a weighted version of the statistic were used (Anderson et al. 1993), because of the aforementioned point that no patients have ratings which differ by more than a single category.

## Discussion

The EEGOS was developed as an extension of the existing GOS, to address the issue of insensitivity. It is based on the GOS because of the many advantages inherent in using a scale which is already familiar, and as widely used and successful as the GOS. It fulfills the criteria suggested by Rappaport et al. (1982) in that it is easy and very quick to use.

### *Comparison with existing studies of the GOS*

Maas et al. (1983) published raw data for 'non-live' ratings (i.e. based on written information not face-to-face interview in a similar method to the 'retrospective ratings' described here) on the GOS by four independent observers. Thirty seven patients were assessed by interview at times between 6 and 12 months after injury, and similar data to the RQ and cognitive functioning test scores were presented to the raters who then scored the patients using the GOS. As no patient was dead or vegetative the choice of GOS was therefore restricted to severe disability, moderate disability or good recovery. Four raters gave overall agreement on 68% of patients, and 6 different pairwise comparisons, with calculated kappa values ranging from 0.62 to 0.79. Much of this variation is the result of differences in the marginal distributions of scores for each rater. For example, rater 1 graded 38% of patients as moderate disability (GOS 4), whereas rater 2 graded 62% as moderate disability (GOS 4). This dependency of kappa upon the marginal distributions has been noted by several authors (Svensson, 1993). If we choose the comparison between raters 3 and 4, then the marginal distributions are most similar to the EEGOS data presented here, with a kappa value of 0.79 and a percentage agreement of 86%.

A study by Brooks et al. (1986b) looked at the reliability of the original GOS using only the three categories severe disability, moderate disability and good recovery, and a revised version of the GOS which enabled distinction between 'high' and 'low' grades in each category. Two raters assigned scores to 51 patients on both the three and six point scales on the basis of their neurosurgical casenotes. They reported 70% agreement using the GOS, falling to 46% on the six-point version, giving kappa coefficients of 0.55 and 0.34 respectively. These percentage agreements are of the same order as those obtained in the

'retrospective' study using the EEGOS. However, use of the EEGOS in the 'live' study gave higher inter-rater agreement.

### *Retrospective Ratings*

The pilot study of retrospective ratings was carried out to look at the likely usefulness of such a scale based on written information about a patient. This was a similar methodology to that used and described by Maas et al. (1983) and enabled us to draw comparisons between the reliability of the EEGOS and the existing GOS.

The results show that the behavioural scale gives the least consistent and the physical scale the most consistent scores amongst raters. This is perhaps not surprising in view of the facts that the ratings are 'retrospective', and there is a relative lack of subjectivity in assessment of physical problems. Behavioural problems following head injury are notoriously difficult to assess (Pentland and McPherson, 1994) and have been shown to relate strongly to stress in relatives and carers (Hall et al. 1994; Brooks et al. 1986a). It may be the case that someone with severely disturbed behaviour is capable of living independently. The reports of behavioural change are much more subjective in terms of the relatives' observations, and also in the way in which these written records are interpreted by the raters. Information from a written questionnaire is restricted to the questions asked, and the limited range of possible answers. The results would suggest that this subscale needs further modification to define the classification criteria in more detail, especially if it is to be used in the retrospective situation.

As mentioned above, in one instance (Subject 6) the raters differed by two categories in assessment of behavioural/emotional function: one rater scored 3 (severe disability), one scored 4 (moderate disability) and one scored 5 (good recovery). Although this might suggest that the subscale is unreliable, the patient is an interesting case and worthy of discussion.

The subject, a 69 year old man, with a long-standing history of alcoholism, was well known to the police, having been found 'drunk and incapable' on a number of occasions, and sustained his injury from a fall in the street whilst intoxicated. Following treatment in the neurosurgical unit, he was transferred for a short period of rehabilitation, and then discharged home. However, after being discovered by the police on several further occasions following bouts of binge drinking, he was eventually admitted to long term care 'for his own safety'. At the time of his assessment he was an in-patient in a geriatric ward.

The information supplied in the Relative's Questionnaire was completed by his sister, who commented that she had not noticed any change in his behaviour as a result of his accident. However, his situation had changed in that he was now in long-term care, having previously lived at home.

Thus, it can be argued that the subject should be given a score of 3 (severe disability) because his behaviour has warranted long term care, whereas prior to his head injury he was living independently. Equally, it can be argued that he should be given a score of 5 (good recovery) because his behaviour is reported as being unchanged since his injury and it is only his situation which is altered. One can only speculate on whether he would have needed long term care in view of his age and frequent drinking binges irrespective of his head injury. This serves to illustrate the difficulty in assessing outcome in the head-injured population. It seems likely that such a case, which is by no means atypical, would lead to the same arguments when assessing outcome using the GOS.

### *'Live' Ratings*

Ideally, the EEGOS should be used when the patient and a relative are seen in a face-to-face interview, such as during a clinic appointment. This gives more insight into the patient's behaviour and questions can be asked if the relevant information is not available. These preliminary data suggest that the EEGOS is more reliable during 'live' rather than 'retrospective' assessments, supporting the advantage of using it as a quick measure in out-patient clinics.

The EEGOS has been developed as a modification of the GOS and we foresee its usefulness primarily in population studies of brain injury. As pointed out by Frattali (1993), 'no single tool will serve all needs' and the EEGOS is intended to be used for purposes currently fulfilled by the GOS, and to complement scales such as the Disability Rating Scale. It is hoped to prove useful in multicentre trials of brain injury, and to enable comparisons between groups, such as comparing regional and national averages. In addition, we hope to design a scale which can be used on the basis of written information, such as that gathered using a Relative's Questionnaire, whereby patient outcome can be estimated without the need for face-to-face assessment.

Although there are very few patients in the pilot study of the EEGOS, and considering all the deficiencies of using an overall measure of agreement, it would appear that the inter-rater reliability is comparable to that of the GOS, applied in similar circumstances. We

believe that this is an encouraging step forward and further studies are planned to investigate its reliability and validity in more detail.

### Acknowledgements

We gratefully acknowledge the support provided by the Scottish Office Home and Health Department (Grant No. K/RED/4/C177), the MRC Clinical Research Initiative (Grant No. G9301975), and the Association of British Insurers for their ongoing support. We would also like to thank Shirley Anderson, Sarah Cudmore, Patricia Jones and Kath McPherson for their help in the pilot studies, and Brian Pentland for helpful comments on an earlier draft.

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